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JUNE 1937

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MONTHLY WEATHER REVIEW

Editor, EDGAR W. WOOLARD

VOL. 65, No. 6
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JUNE 1937

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A SERIES OF RADIOMETEOROGRAPH SOUNDINGS DURING FEBRUARY–APRIL 1937

By C. HARMANTAS and D. P. KEILY

[Massachusetts Institute of Technology, Cambridge, Mass.]

LABORATORY PROCEDURE AND RESULTS OF ASCENTS

By C. HARMANTAS

INTRODUCTION

The release of 31 radio sounding balloons at the Massachusetts Institute of Technology during the months of February, March, and April 1937 was a joint program of the Harvard Blue Hill Observatory and the Institute. The Blue Hill Observatory having developed the meteorograph wished to demonstrate its reliability and to show that it could be operated and consistent results obtained by persons other than the inventor. The Meteorological Department of the Institute having a program of upper-air research, particularly in connection with hurricanes, wished to test this instrument, acquire familiarity with its operation, and decide if it would be suitable for use in its investigations. In addition it was thought advisable to see if the records could be evaluated in a sufficiently short time to be used for synoptic purposes, to compare results with those of the airplane meteorograph, and to decide whether the radio instrument could supplant the airplane. For these purposes launchings were made from the Massachusetts Institute of Technology at the same time the airplane took off from east Boston. Particular attention was given to the development of techniques for preparing and launching the radio instrument and to the reduction of these operations to a routine procedure.

It was originally intended to release an instrument each morning for 30 days in succession, with the hope that in this period both good and bad weather with strong winds and precipitation would be experienced. However, most of the ascents were made in fair weather with clear skies and light winds. In order to make as many tests as possible in bad weather, the schedule was broken several times when fair weather prevailed over long periods. Finally, after 24 instruments had been released, and only 2 stormy days had been encountered, the series was stopped and the remaining instruments were subsequently released in stormy weather only over a period of 4 weeks.

The results obtained from these ascents, even from those made in bad weather, justify use of this instrument for synoptic as well as research purposes. While the instrument needs improving, especially on the matter of "contacts", the present deficiencies are not very serious and should not prevent the use of the instrument even in its present state.

INSTRUMENT

A very brief description of the instrument will be given here; and the reader is referred to the Bulletin of the American Meteorological Society, May 1936, for complete details.

The conventional, but tiny, meteorograph elements carry affixed to them short arms which describe an arc on the surface of a narrow cylinder as each element is actuated by its respective force. These elements are mounted about the cylinder at such angles that their pens do not interfere. In addition, there is a dummy pen resting on the cylinder, but fixed in position and serving as a point of reference. A helix of fine wire is wound on the surface of the cylinder, embedded in insulation, then ground down flush with the cylindrical surface so that the wire is exposed and a smooth surface made for the pen arms to slide on.

The cylinder is revolved by a clock at the rate of two revolutions per minute. As the revolving helix comes under any one of the pens an electric circuit is closed which gives out a radio signal when in flight or actuates a recorder relay when in the laboratory. As long as all pens remain stationary they will be at a constant distance from the reference line and their contacts will have the same relationship with respect to time. If a pen should move, contact will be made either sooner or later than at its previous position. This variation in time is a measure of the change in the meteorological element actuating that pen. Contacts are recorded in a similar fashion. To facilitate readings, instead of using a revolving drum, paper is fed at a constant rate past a moving pen. The pen itself is carried across the paper on an endless chain at such a rate that it returns to the starting edge after each revolution of the helix. Each time that a contact is made by the instrument, a relay trips the pen and a mark is left on the paper. As long as all motions are uniform, distances between contacts on the paper are a measure of time and of the magnitude of the element to be measured. It follows that contacts must be positive and sharp either at "make" or "break", otherwise measured distances will be inaccurate and errors will result.

Theoretically the instrument has an accuracy of 0.1° C. in temperature, and in these experiments this accuracy has often been attained. However, in some cases contacts have varied in length as well as missed altogether for considerable periods. This variation in contact length reduced accuracy to about 1° C. Pressure contacts have also given some trouble, although not as much as those

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of temperature. In actual flight, contacts from the pressure element fall on a regular curve, and whenever contacts are imperfect the curves can be smoothed over short intervals without loss of accuracy. Humidity contacts were the least troublesome because the range for humidity was so large that variance in contact length caused a discrepancy of less than 1 percent. It was found that a large range of the humidity pen was an impediment to rapid evaluation. As a result, the humidity pens of the later instruments had a smaller range, the contact error for humidity then being of about the same proportion as for temperature. It may well be that a heavier wire on the helix or a different type of pen will give better contacts; at any rate, more work should be done on the instruments to improve them.

CALIBRATIONS

All the meteorographs were calibrated in the Massachusetts Institute of Technology pressure-temperature calibration chamber, in which calibrations for temperature, for pressure at room temperature, and for pressure at low temperature were made for each instrument. At Harvard one instrument was calibrated at a time, but if a chamber could accommodate several instruments, and a recorder were available for each, all could be calibrated in the same time that would be required for one. The Massachusetts Institute of Technology chamber is a large one, but only one recorder was available; nevertheless four instruments were calibrated at a time.

Wires were led out from each instrument to a panel near the recorder. When a steady state was reached within the chamber, an instrument was switched on for about a minute, or until the complete cycle was covered, then disconnected and another instrument switched on. After all instruments had thus recorded, the chamber was cooled (for a temperature calibration), and a sufficient time allowed until a steady state was reached; the above procedure was then repeated.

At first considerable difficulty was encountered in identifying the various elements. With only one instrument in the chamber all changes are shown on the record as they occur; and identification is easily made. In the method just outlined only a few points are recorded from each instrument and as the record is discontinuous, time is required for orientation. For a pressure-temperature calibration, the humidity record is not needed, and if it were disconnected, confusion would be considerably reduced in multiple calibrations. The instruments are now manufactured so as to facilitate this; the humidity pen is constructed so that for either a temperature or pressure calibration it may be placed in the "off" position. Furthermore, for a temperature calibration, the pressure remains constant, and conversely the temperature remains constant in a pressure calibration.

It follows that, besides the line of reference contacts, there will be one more line which will not vary. For any one instrument there will be three contacts throughout the calibration, two of which will be separated by a constant distance, and the remaining contact is that of the element being calibrated. By considering each instrument separately, points are easily identified by the above process of elimination and marked with a distinguishing color. There is a further saving in time when multiple calibrations are made: whatever computations are required for the reduction of pressure data will be applicable to all instruments alike, hence such computations are made only once.

Having identified the various elements and determined their distances from the reference line, calibration curves are plotted in the same way as for an airplane meteorograph with the following variations: both temperature and pressure elements on the instrument have a range of two or more turns of the spiral, while the recorder gives deflections as though from only one turn. Parallel reference lines are plotted on paper at distances equal to the *recorder cycle*, and measured deflections from the recorder are plotted a corresponding distance from the appropriate reference line. With only three such reference lines for the entire range of an element no question arises as to which reference line is to be used for any point.

Humidity calibrations are made in a separate chamber; all four pens are allowed to make contacts but three of them are separated by constant distances. The varying contact is that of humidity while the remaining three are identified by noting their relative positions and by referring to the calibration curves of pressure and temperature.

The temperature element of the instrument is excellent and its calibration curve is almost a straight line. In addition these elements are so uniform that their calibration curves have approximately the same slope. The comparison of all curves showed a maximum difference of 2° C. If a tolerance of 1° were permissible, the instrument, in capable hands, could be used without calibration for an ordinary synoptic ascent.

RELEASING

Prior to release, the instrument was placed in the pressure chamber and the pressure was first reduced to about 50 millibars and then allowed to return to atmospheric pressure. Inasmuch as pressure calibrations were made after the aneroid had been exercised, it was thought desirable to release the instrument with the aneroid in the same state as during calibration. A few tests made lately showed that the differences between readings in either state were less than the precision with which they can be read. However, further tests should be made before the above procedure may be considered an unnecessary refinement.

The radio is attached to the meteorograph and the assembly is tested and carried to the instrument shelter where it remains for about 5 minutes in order to acquire a steady state in the proper environment. Meanwhile the radio receiver and recorder are started and the signals are observed as the contacts are made. If contacts are satisfactory, the instrument is attached to the inflated balloon and released.

BALLOONS AND LAUNCHING

At the beginning of the series, two balloons were used: one filled to about 1,000 grams lift serving as the tractor and another with approximately 600 grams (depending upon the weight of the instrument) to act as a parachute. Both balloons being alike the larger one was expected to burst and the smaller one to check the speed of descent of the instrument. In two instances the descent was followed; in both cases the rate of fall was slow enough to indicate that the second balloon was intact. The two balloons were tied as closely together as possible. Previous ascents with long leads between the balloons proved unsatisfactory, because turbulence acting on the balloons separately caused violent and irregular motions of the instrument. With both balloons tied together there is always a fear that fragments from the burst balloon may tear the smaller one and that the instrument may then

fall freely to the ground. The fact that one instrument was found on the sidewalk in a thickly settled district shows that this fear is not groundless. The last six instruments were released with one balloon each and with a parachute inside of the balloon. With this method there is a probability that the lines may foul, preventing the chute from opening; even if it is fastened below the balloon, there is danger of the parachute icing in stormy weather. One balloon with a parachute is to be preferred, but the design and location of the parachute should receive further study.

Launchings were made from the roof of the Guggenheim Building. This was not a favorable location because of the maze of antennae wires and the close proximity of taller buildings. The balloons were filled in a penthouse and then carried to the lee side and launched. Difficulties were experienced in handling and launching the balloons even in moderate winds. It is fortunate that at no time was the wind stronger than 25 miles an hour, otherwise it is feared there would have been many failures. It is essential that some form of launching device be used and that more experiments be made with parachutes to develop a suitable method of fastening in order to insure safety.

Rates of ascent vary over wide values depending upon whether one or two balloons are used. According to the instrument manufacturer, high rates of ascent are desirable in order to get as great an altitude as possible before the radio signal becomes too weak to record. With the new battery system developed in the Massachusetts Institute of Technology laboratory, radio signals can be heard for several hours. Therefore lower rates of ascent can now be used with the following advantages: (1) The temperature indications being made once every 30 seconds, a more detailed picture of temperature variations will be available. (2) The hair hygrometer with its characteristic high lag will now have more time to acquire the correct reading. (3) Less hydrogen will be required and greater altitude will be reached.

The unsatisfactory readings from the hair hygrometer in these tests as compared with those from the airplane meteorograph are wholly due to the high rates of ascent of the balloon. As far as the temperature element is concerned, its characteristics are such that slower rates of ascent and consequently reduced ventilation will not affect its readings.

With two balloons the rate of ascent varied from 150 to 200 meters per minute, while with one it increased to 300 meters and more. An ascensional rate of 100 meters per minute would be satisfactory except in the cases of temperature inversions and icing conditions. Rates of ascent have been observed to decrease at temperature inversions; and balloons have ceased climbing and have even descended when in clouds under icing conditions. Whenever, in the operator's judgment, these conditions prevail, higher rates of ascent should be used if soundings are desired through and above the cloud layer. A few cases occurred where the balloons descended several kilometers and then rose again. At first thought it would seem to be some instrumental defect, but both temperature and humidity traces showed corresponding changes. Irrespective of which "climb cycle" was evaluated, the results were the same.

In June 1936 some preliminary tests of the radio meteorograph were made at Elmira, N. Y., during which Jaumotte meteorographs were released simultaneously with the radio instruments. In one instance a radio instrument showed pressure and temperature changes corresponding to a descent of about 2 kilometers and then a resumption of ascent. Luckily the Jaumotte instrument accompanying this ascent was recovered; it too showed a similar behavior. The record is shown in figure 1.

EVALUATIONS

Rapid evaluation of the recorded signals is important if the data are to be used for synoptic purposes. For this reason the recorder should show incoming signals in such a form that the operator can pick out suitable points. If signals are received on a tape recorder, even a skilled observer cannot select desirable points by inspection alone. Evaluation of all signals is unnecessary and requires considerable time. A drum recorder similar to a chronograph is better than a tape recorder in that signals are shown to better advantage, but with the drum it is necessary to wait until the ascent is completed before starting evaluation. It is for these reasons that the more expensive recorder described earlier (p. 219) is used. Not only are the signals shown in the most desirable method but evaluation can be started almost immediately after the instrument has been launched.

A copy of a record is shown in figure 2. If the traces of an airplane meteorograph record were moved closer together so that they intersected, the result would be very similar. It is important that the elements be identified before the evaluation is started. This can be done in one of two ways: (*a*) With known surface data (i. e. temperature), refer to the calibration curve and measure the distance from the reference line to the temperature reading. This same distance set off on the record will be found between two contacts; one will be temperature the other reference. Their relative positions will be the same as on the calibration curve. This is repeated with the pressure reading. (*b*) By waiting a few minutes after launching, identification is quickly made by inspection; contacts made by the reference pen will be on a straight line. Those made by the temperature element will form a line sloping to the right as temperature decreases while pressure contacts will form a line sloping to the left. Having identified them, a colored line is drawn across the contacts of each element. By having a different color for each element there will be no confusion of distances in the evaluation. From this point on, the evaluation is the same as in airplane meteorograph procedure. Points are selected and numbered on the temperature and humidity traces, and corresponding ones set on those of pressure and reference. To determine the value of an element at a given point, its distance from the reference line is measured with a pair of dividers, this same distance is set off on the calibration curve, and the value is then read off the scale. For any one measurement there can be read about three values, only one of which will be correct. For example, on the trace in figure 2 the correct temperature for point number 3 is read as $-4.5°$ C. The other values are -28.2 and -41.7. Their separation is so great that no ambiguity arises as to which value is correct. Furthermore the readings of the preceding points indicate on which cycle the temperature should be read. If there is a large gap in the record, the time scale as well as the corresponding values of pressure will guide in the selection of the proper reading.

The speed of evaluation is greatly increased by using thin tracing paper in the recorder. When the thin paper record is placed over the calibration curve, the values of the selected points can be read off directly. With the clock running steadily so that the reference contacts fall on a straight line, this method is the speediest yet developed.

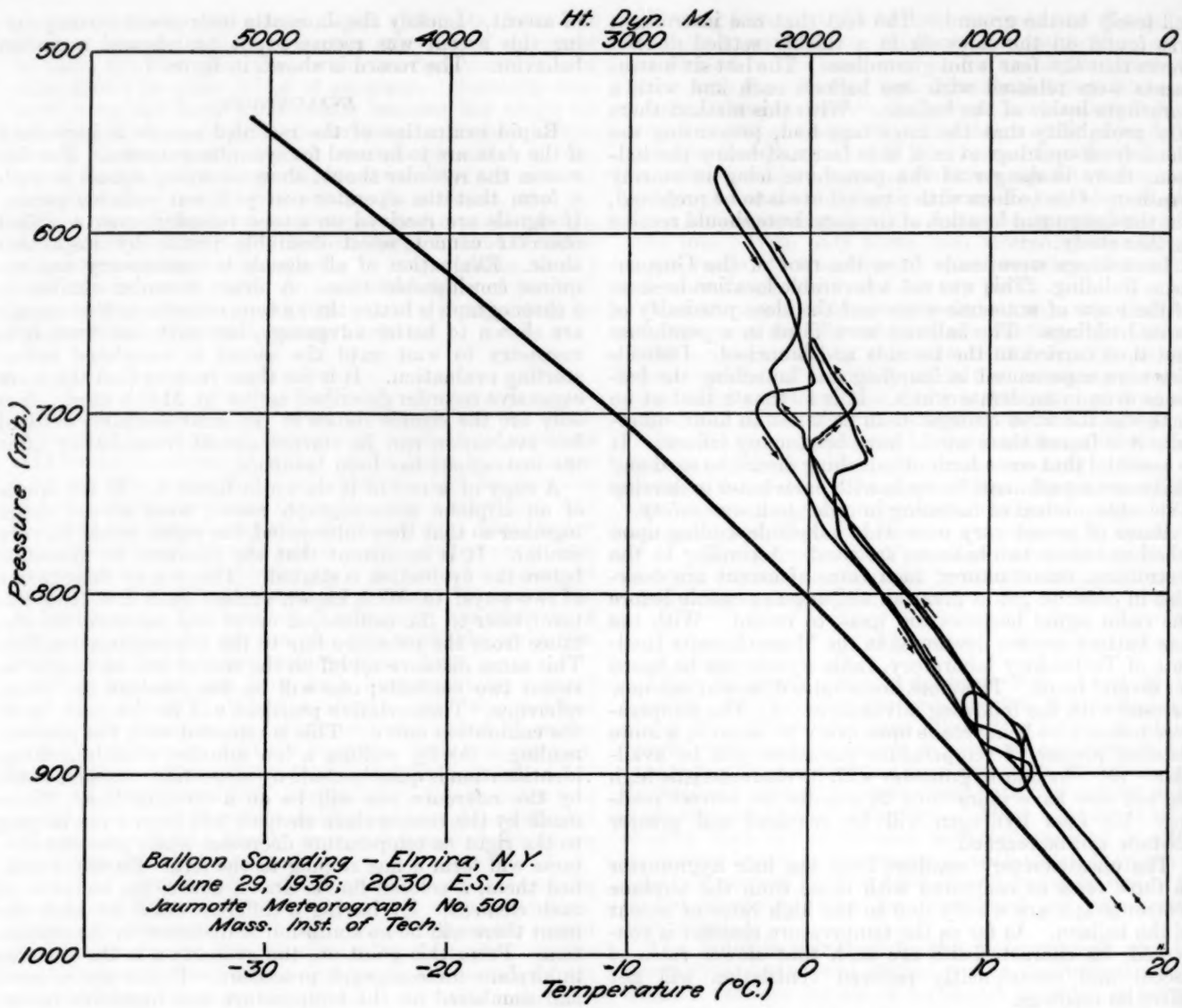

FIGURE 1.

RESULTS

The results obtained are shown in table 1. A brief description of the various items will be made although for the most part the table is self-explanatory.

The variation in weight is due mostly to the different types of A and B batteries and of insulation used.

Although no great attempt was made to launch instruments at an exact time, the table shows only a few minutes variation from 6 a. m. Delays of about 10 minutes occurred when hydrogen tanks were changed, or occasionally when a balloon required patching. It is evident that radio instruments can be launched on schedule with more regularity than airplane soundings.

Under "time legible" is the number of minutes during which the records were of legible quality; the remaining portion had large gaps or weak and irregular contacts. Evaluation of this latter part has been deferred.

A theoretical ceiling of about 20 kilometers is expected considering the amount of gas used and the weight of the instrument; only eight reached an altitude approximately equal to this. The cause for the remaining instruments having low heights is assigned in a few cases to faulty balloons but mostly to the poor quality of contacts and radio performance. An abrupt increase to higher altitudes after February 24 is due to a change in the type of batteries used in the radio transmitter.

Under the column "clarity of contacts" is described the condition of that portion of the record which was evaluated. There were only a few records, and those were short ones, in which contacts were of excellent quality. In the majority of cases, however, contacts were reasonably clear and interruptions, if any occurred, were short, and evaluation could easily be made. There were six records in which one or more elements failed to record for a considerable period, or contacts in general were so irregular that evaluation was made tedious. Four instruments gave such poor records that evaluations were quite difficult and results were of questionable accuracy.

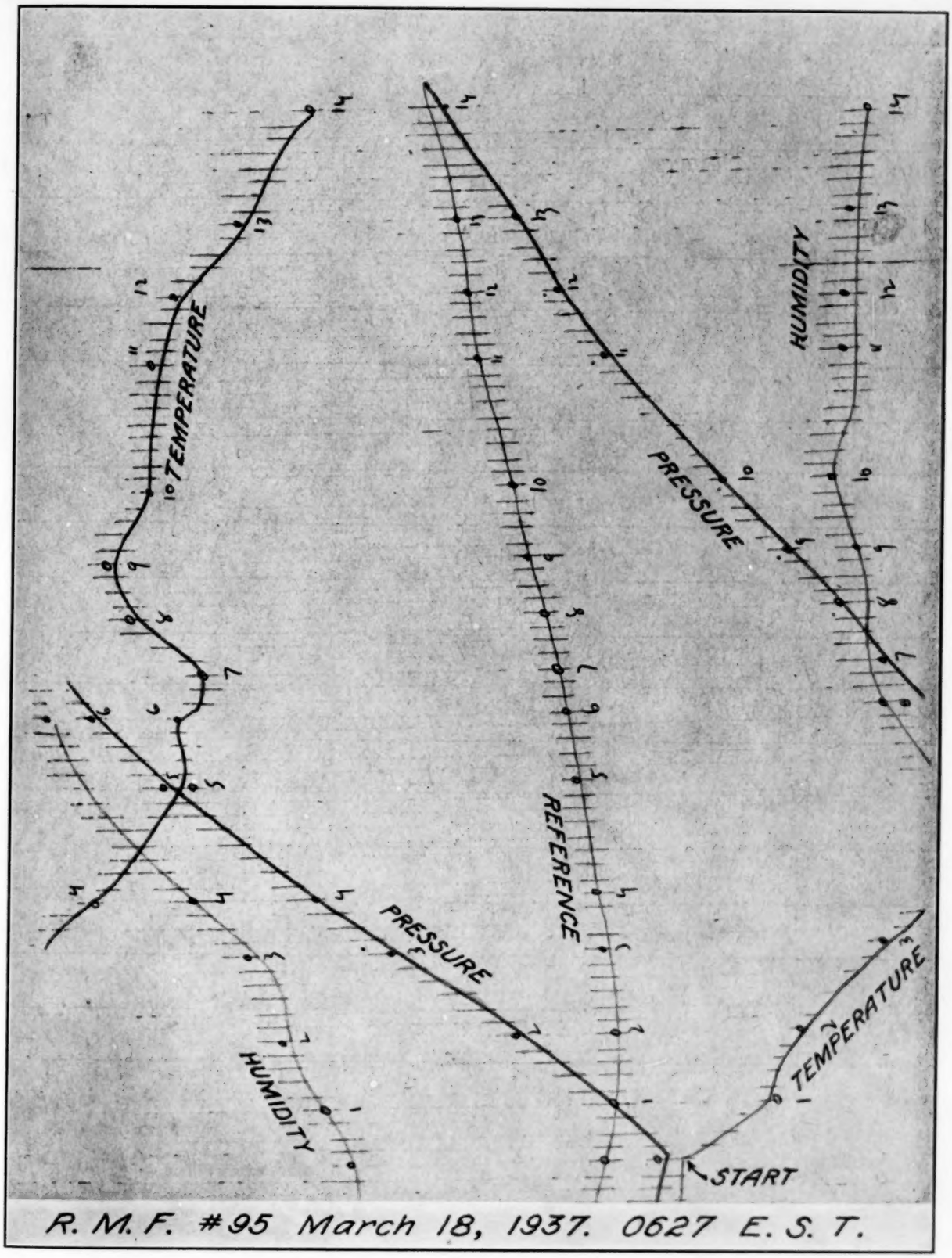
TEMPERATURE
PRESSURE
HUMIDITY
REFERENCE
PRESSURE
HUMIDITY
TEMPERATURE
START
R. M. F. #95 March 18, 1937. 0627 E. S. T.

FIGURE 2.

TABLE 1.—*Summary of Harvard-Massachusetts Institute of Technology radiosonde experiments*

Date, 1937	Inst. no.	Wgt. g	Time release	Balloons and filling	Time legible	Total time	Max. altitude dyn. m.	Strat. alt.	Min. temp.	Contacts (clarity of record)	Rate of ascent m. p. s.	Batteries A	Batteries B	Loss of signal due to—	Time transm.	Remarks
Feb. 17	62	450	602	800–500	------	------	------	------	------	G	------	1	2E	Crash	------	Crashed against bld. P & T pens off. R & F pens on. Good contacts.
18	64	480	550	800–500	51	67	7,660	------	−41.2	G	170–160	1	2E	W. S	745	Very good record, but short.
19	71	475	629	800–500	49	69	9,340	------	−53.2	G	185	1	2E	W. S	1,002	Ref. off. Reconstructed from calibration record and 2 pts that showed during flight. Pres. cont. variable in length.
[1] 22	66	450	618	900–600	75	75	6,320	------	−26.8	G	------	1	2E	W. S. j	850	Excel. R & P cont. Good T cont. Balloon rose and then fell due to icing. Floated for a time and acquired former altitude after 25 minutes.
23	70	480	552	900–600	38	38	7,650	------	−42.3	G	200	1	2E	W. S. j	750	Good P & T contacts. T fair, but variable, double cont.
24	63	480	615	900–600	60	60	8,350	------	−50.3	G	160–150	1	2E$_w$	W. S. j	------	R good. P and T fair, variable cont.
25	76	655	609	------	60	60	12,100	10,050	−64.3	G	------	1	2B	W. S	801	R good. P contact good but irregular. T contact very short and missing over portion of record.
26	75	490	600	------	63	63	15,900	8,100	−44.2	F	------	1?	2E$_w$	W. S. j	745	P cont, variable. T intermittent, poor for last 15 min.
27	72	635	555	1,030–730	*83	118	15,500	9,100	−55.5	G	------	2	2E$_w$	Distance sig. heard w	810	*Ascent only. R excellent. P wk at start, var. cont. better near midpoint. T double cont. some irreg. Clock slowed down at end.
28	73	525	604	1,030–730	81	81	18,760	10,400	−54.7	G	------	2	2E$_w$	W. S	805	R Excellent. P & T very good. Clock slowed last 15 min.
Mar. 4	68	530	600	------	76	76	14,880	9,720	−60.6	G	------	2	2E$_w$	Clock?	------	R Excel. P fair with double cont. and gaps in record, improving to good after midpoint. T fair. Clock slowed near end.
5	79	550	600	930–630	81	81	12,720	8,800	−51.7	G	------	2	2B	Clock	------	R Excellent. P short cont. with gaps. T good.
6	81	670	625	1,000–650	45	45	7,160	------	−41.1	E	160±	2	2B	Filament. S lost abrupt.	810	Very good record.
7	77	690	607	1,000–750	0	0	------	------	------	------	------	2	2B	Filament? S lost in launch.	------	Good contacts until launched, then failed. Filament? Clock?
8	80	680	615	1,000–650	79	121	11,250	10,500	−64.8	G	------	2	2 Bi	W. S. low L?	900	Instr. followed in descent. to 4 km.
9	82	550	617	------	102	105	21,250	9,250	−56.8	F	------	2	1 Bi	W. S	------	Ref. & P good. T fair, var. length double cont., difficult evaluation.
10	78	545	616	1,030–600	85	98	19,000	6,950?	−49.2	G	------	2	1 Bi	W. S. bat. failure	------	Good contacts, P somewhat irregular double cont.
11	69	------	612	------	63	76	9,680	9,350	−53.3	P	------	2	1 Bi	W. S. bat. failure	830	R & H good. P double cont. and var. length. T very poor, large gaps in record. A good record. Very short R.
12	89	------	559	------	75	80	13,800	9,500	−55.4	G	------	2i	1B	W. S. bat. failure	844	T few double cont. and few irregular lengths.
13	91	------	610	------	140	160	18,550	9,200	−54.8	G	------	F$_1$i	1B	W. S. bat. failure. + dist.?	------	All good contacts.
14	96	------	757	------	50	59	11,550	9,200	−51.3	F	------	3i	1B	Clock	945	R & P good. T quite irregular last half of record.
[5] 15	88	------	557	------	105	125	23,700	{9,000 or 11,700}	−57.7	F	------	3i	1B	W. S	------	T irregular and wk. last half.
16	99	------	601	(3)	------	47	8,500	------	−41.8	------	------	3i	1B	W. S	------	
17	97	------	601	------	93	93	18,840	8,000?	−53.1	F	------	3i	1B	W. S	------	Receiver failed after 7 minutes, reception. Repaired and reception resumed after midpt. All cont. double and irreg. Clock very slow!
18	95	------	627	------	102	120	17,300	9,200	−52.8	G	155	F$_1$	1B	W. S	------	R, H, & P good. T week and irreg. after quarter of flight.
[1] 25	90	------	1,305	(3)	------	138	16,850	9,100	−53.2	G	210	F$_1$	2B	W. S	1,600	R, H, & P good. T irreg. with large gaps in record. 1st flight using 1 balloon and parachute.
Apr. [1] 2	92	600	1,423	(3)	79	79	------	------	------	P	------	3i	1B	W. S	------	No pressure contact! No evaluation.
[1] 2	154	690	1,655	(3)	73	73	10,820	8,700?	−54.5	F	220	3	2B	W. S	------	Ref. good but double cont. P irregular and missing. T irregular and variable.
[1] 6	152	685	951	(3)	26	74	5,450	------	−11.5	P	205	3	2B	Clock? W. S	------	P and H good. T failed after 24 min. Ref. failed after 20 min. Clock slowed near end.
[1] 9	153	650	1,345	(3)	------	58	10,500	------	−43.0	P	±300	(4)	2B	W. S	------	Very poor record! Temp. very poor with large gaps. P no contacts for 1st half. Evaluation made assuming a constant rate of ascent to pstn.
16	------	695	1,204	(3)	9½	9½	------	------	------	G	±300	3	2B	Filament?	------	Abrupt failure! Record not evaluated approx. ht. 4 km.

[1] Rain.
[2] Snow.
[3] 1 balloon, 1,400 grams.
[4] 1 large F. Special tube.
[5] Special balloon, 2,000 grams.

After the first few days, the special effort to transmit the results as quickly as possible was discontinued. They were then transmitted about 2 hours after the instruments were launched. Actual times varied, depending upon the duration of ascent and the quality of the record. If a steady schedule of releases were maintained, results could be on the line about a half hour after the completion of the ascents.

COMPARISON OF RESULTS WITH THOSE OF AIRPLANE METEOROGRAPH

Previous comparisons between balloon soundings and those made with an airplane had been made by the Institute on three separate occasions. In the course of upper-air studies with Jaumotte instruments over St. Louis, Mo., data were compared both with those of the Weather

Bureau, and with an independent set of soundings made by the Massachusetts Institute of Technology airplane. The results from all these were in close agreement.

Similar agreement at Boston was expected with the radio meteorograph, but temperatures obtained by the airplane instruments were higher by over 2° C. The two curves when plotted on the same charts showed consistent discrepancies, with the curve from the airplane meteorograph displaced to higher temperatures. In figure 3 is shown an adiabatic chart on which simultaneous soundings by airplane and radio meteorographs are plotted. Since the radio instruments were individually calibrated, a consistent difference with the airplane meteorograph meant that either the Massachusetts Institute of Technology thermometer was in error or the calibration of the airplane meteorograph was inapplicable. Moreover the first temperature reading of flights always agreed, from which we deduce that discrepancies were not due to errors in standard thermometers but to calibrations. The airplane meteorograph was recalibrated on March 18, first in the Massachusetts Institute of Technology laboratory and later by the Weather Bureau. Due care was taken not to disturb the instrument or change its adjustment prior to these calibrations. In both cases the new temperature calibration was found to be different from that which was made in December of 1936. It was from the latter curve that temperature determinations were made during comparative tests with radio meteorographs. Since the radio soundings were made during March, the calibration made in that month would probably be more applicable than the one made in December, as the instrument could have changed in calibration either suddenly, or gradually over a period of weeks. However, the consistent variation from radio meteorograph records shows that its calibration

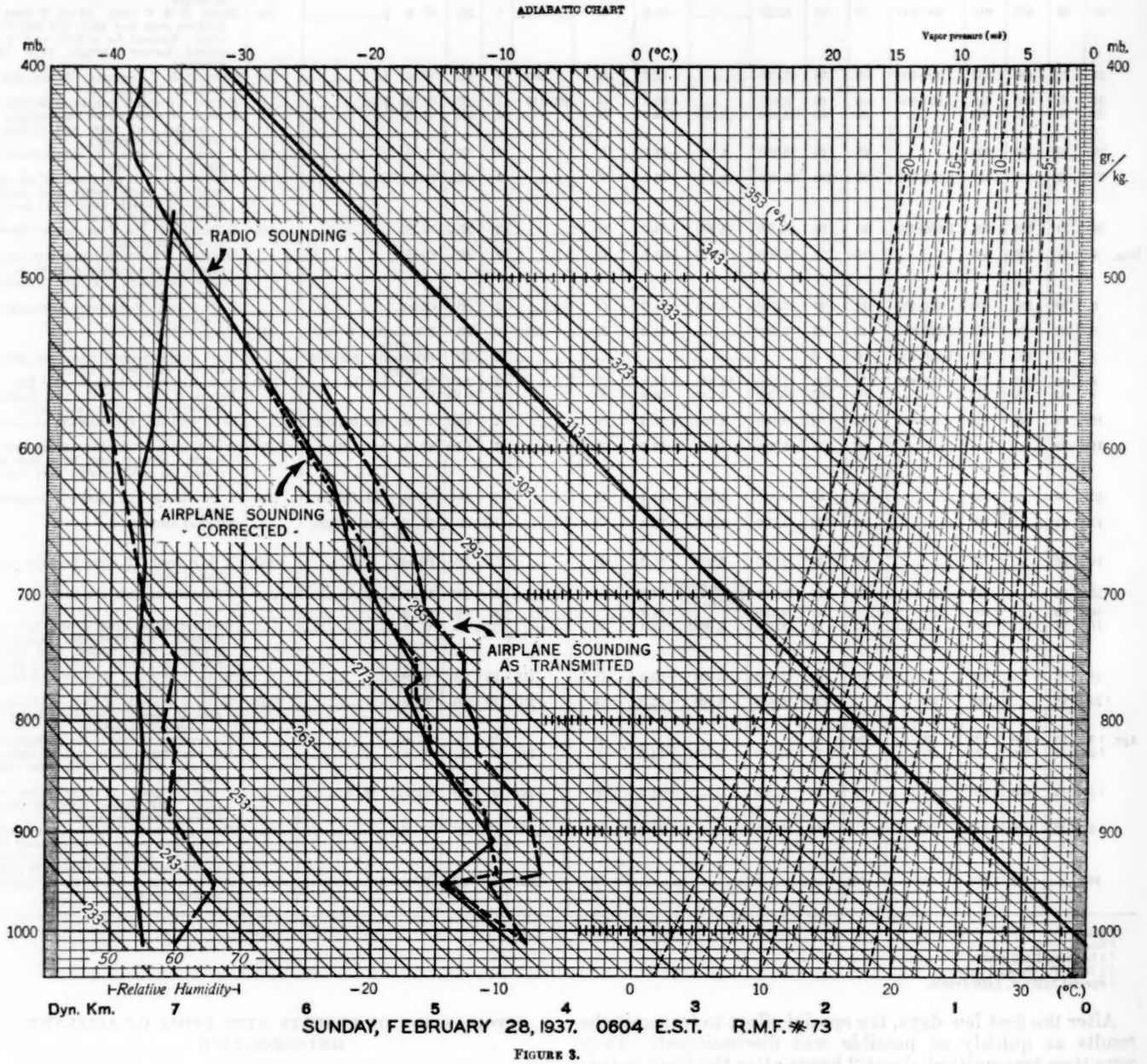

FIGURE 3.

remained unchanged during the testing period; therefore the instrument must have changed calibration before February 17, 1937.

The March and December calibration curves are shown in figure 4. If the data as transmitted (based on the December curve) are recomputed using the March calibration, results from the radio meteorograph show excellent agreement with those from the airplane instrument. On March 18 the airplane carried a different meteorograph; the results of that day, which are indicated in figure 5, show good agreement. No more comparisons could be made because the series was discontinued with that day. Additional tests were made by sending up the two meteorographs in the airplane; both showed good agreement. The record from the "questionable" meteorograph was evaluated twice; once with the calibration of March and again with that of December. With the latter calibration, the values were displaced from the March values in exactly the same manner as the radio meteorograph values were.

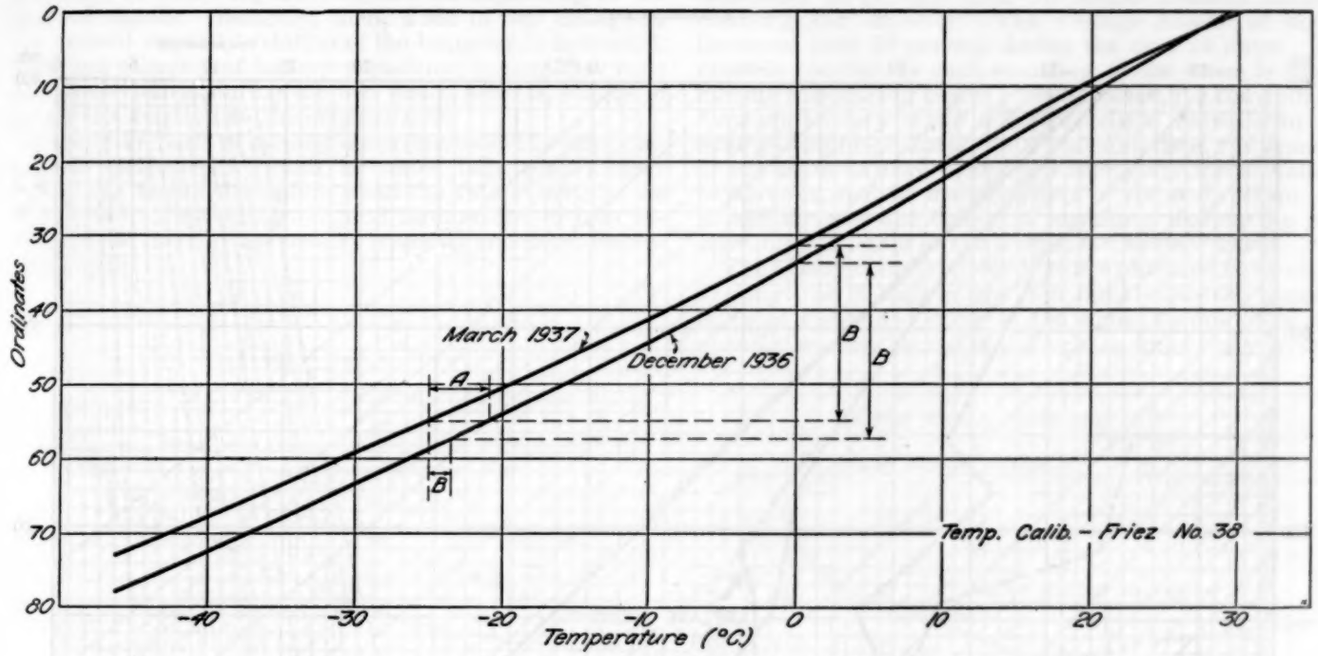

FIGURE 4.

Irrespective of the type of instrument used in making an aerological sounding, it is necessary to take check readings just before the ascent, and the reference line on the calibration curve should be established from them. A base reading made indoors, especially in winter, may lead to serious errors should the instrument be out of adjustment. By making settings at the outdoor temperature, instrument readings will be correct at the take-off and variations from true values at higher altitudes due to faulty calibration will be reduced considerably. The following example, referring to the calibration in figure 5, will make this clear: Assume a usual winter condition with a surface temperature of 0° C. and a minimum temperature of −25° C. If the base line were established from a room temperature reading (about 20° C.), the calibration curve will be used over a 45° range of temperature and the error due to faulty calibration would be 4° C. as shown at A. On the other hand, if the base line were established from zero degrees (the temperature at take off), the error would be only 1°— as indicated at B.

Although it is more difficult to establish a base from readings outdoors, it is necessary that this be done in order to reduce the magnitude of calibration errors. As an additional safeguard the instrument should be calibrated more frequently.

Furthermore, in plotting the adiabatic chart, the surface temperature should be that from the instrument and not the shelter reading. If the calibration curve is correct and the base line set from the shelter reading, both values will of course read the same. Otherwise, the initial lapse rates will be false, and depending on the error of calibration, nonexisting inversions or very steep lapse rates may be indicated.

With the exception of the additional trouble involved in the drawing of a separate calibration curve for each radio meteorograph, this instrument has certain advantages over the airplane meteorograph. Surface readings from the instrument are checked against those in the shelter. Then relative distances from all contacts are compared on the calibration curve, and any change of adjustment of the instrument will be apparent before it is released. Besides the advantage of obtaining higher altitudes than the airplane, the radio records can be evaluated with a considerable saving in time because they may be worked out simultaneously with the ascent.

NOTES ON TUBE AND BATTERY TESTS IN THE LABORATORY AND DURING FLIGHT

By D. P. KEILY

In connection with the preparation and release of the Harvard radio-meteorographs used in this series of upper air soundings, a short study was made, under controlled laboratory conditions, of the operation of the tubes and batteries supplied with the radio portion of the instrument.

It was found that the average height of ascent could be consistently increased, except for instruments otherwise defective, by a better choice of the relative capacities of plate and filament batteries, without any increase in total battery weight.

Preliminary tests on a new type of radio tube, especially designed to be directly connected to a 1½-volt dry cell, indicated that, when substituted for the type used in the present meteorograph, it will probably not give equal results. However, it has inherent advantages which merit further tests and study, in order that it may be adapted to use in new radio-meteorographs.

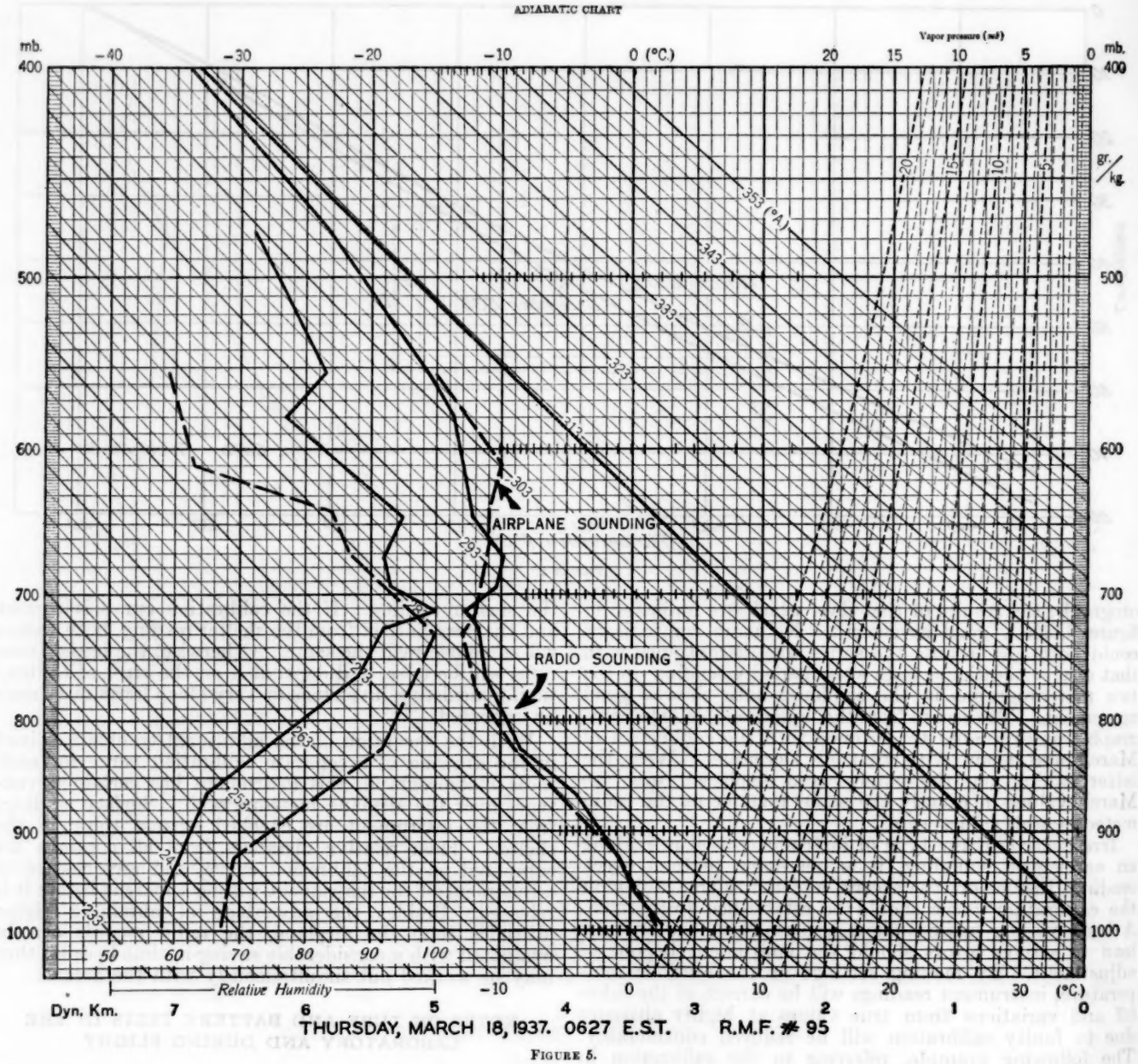

FIGURE 5.

Test for least battery voltages at which radio continues to transmit.—In actual flight the battery voltages are rapidly reduced as the instrument ascends, since the low temperatures stop the chemical action in the cells. Unless special precautions are taken to heat or insulate the batteries, the voltage will fall faster due to freezing than to the power drain of the radio transmitter.

The radio transmitter from a sample meteorograph was connected to sources of continuously varying power. The plate and filament potentials were reduced separately and together to determine the voltages at which the tubes ceased to oscillate. The normal filament voltage of two type 30 tubes, as used in the Harvard radiometeorograph, is 4 volts. A commercial unit battery of 4½ volts potential is supplied with the instrument. The filament cut-off voltage, at rated plate voltage, was found in this case to be 2.6 volts, which is 65 percent of rated voltage, or 58 percent of initial battery voltage. The usual plate voltage applied to this type of tube is 90 volts. The plate cut-off voltage, at rated filament voltage, was found to be 20 volts. The cut-off voltage at minimum filament voltage (2.6 volts) was found to be 22 volts. The latter value

will hold in flight conditions, as the filament battery loses voltage more rapidly. 22/90 is 25 percent of initial battery voltage. Graphs of battery voltage at normal load plotted against temperature and time, show that both filament and plate batteries of the types supplied froze up and lost voltage at about the same rate, when under continuous load.

In flight, however, the filament load is continuous, while the plate load is applied only about one-sixth of the time, at fairly regular intervals corresponding to the emitted signals. Roughly, then, a six to one change in the present capacity relation of the batteries is indicated. The final selection of battery capacities, chosen after tests and observations during the last dozen ascents, stands in about this relation to the original sizes.

Battery life tests at varying temperatures.—The temperature of radiometeorograph batteries falls continuously during the ascent depending upon the rate of ascent, the lapse rate in the atmosphere, and the amount of heat insulation provided by the battery covering and the meteorograph case.

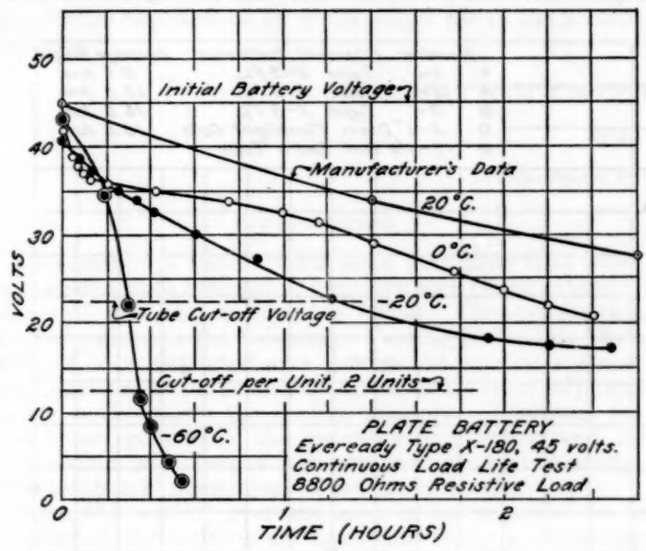

FIGURE 6.

In the laboratory tests, batteries were placed in the cold chamber and immediately put on load test. The batteries then reached a steady temperature at a more rapid rate than they would in an actual ascent. This procedure, however, is the nearest approach to flight conditions that could conveniently be made at the time. These tests were repeated with the same types of batteries at various temperatures from 0° C. to —60° C.

To find the actual temperature-time-voltage relation for any battery, it would be necessary to assume that the battery operated for a short period on successively lower temperatures, and study the time-voltage relation on several curves at different temperatures.

Results of the temperature tests are shown graphically in figures 6 and 7. It is important to note that although the nominal cut-off voltage for radio purposes is given as 34 volts per 45-volt unit, in this radio transmitter the cut-off voltages are much lower, and it is possible to obtain the extra life afforded by a slight leveling off of the otherwise steadily falling voltage characteristic in the neighborhood of 30 volts. Long battery life is important not only to permit of reaching great heights, but also to allow the use of a slow rate of ascent, in order that errors in measurement due to the varying lag of the different measuring elements may be minimized.

Flight tests with various battery combinations.—The first 6 instruments used one very small filament battery, type Burgess X–3–FL, and two small layerbuilt plate batteries, National Carbon type X–180. Previous experience with small batteries indicated that the short duration of these flights was due to a premature failure of the filament battery. A second battery of the same size was then connected in parallel with the single filament battery, doubling the capacity. The average height of flights increased over 50 percent during the next 10 days. The altitude reached by each sounding of the series is shown in daily sequence in Fig. 8. The addition of a third similar filament battery made a further slight increase in the average height of ascent. At the same time, the removal of one plate battery, thereby reducing the initial voltage to 45 volts, had no definite effect in either direction. It should increase the height, if anything, due to the considerable reduction in the weight of the instrument.

The average heights given here are obtained from values varying over a wide range. In most cases the impossibility of assigning failure of the signal to one of several possible reasons makes it difficult to know very exactly

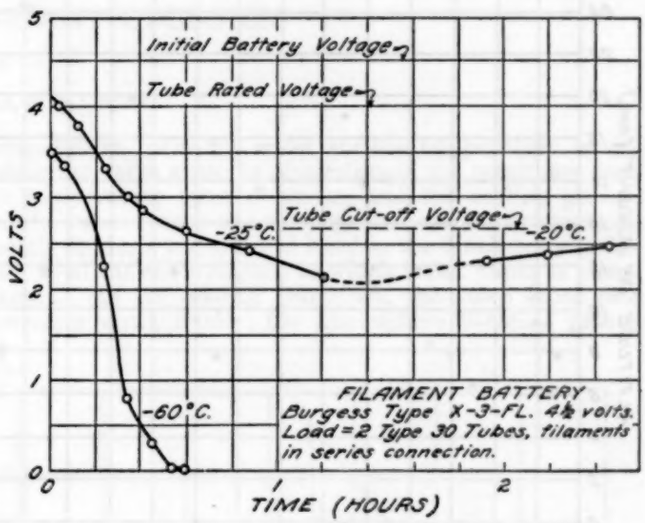

FIGURE 7.

the effect of particular changes in battery sizes. On the whole, however, it is justifiable to assign the considerably increased height of ascent to the increased filament battery capacity, since no other factor was varied in any definite and abrupt manner during the entire series.

Because of the expense and inconvenience of using several small filament batteries in parallel, a single battery of three small flashlight cells (1″ dia.) was used in three of the last flights. The capacity was somewhat greater than that of three small batteries in parallel. The altitudes attained were 19.2, 18 and 18 kilometers, respectively. The average of these is higher by 2 kilometers than that for the flights with three special batteries in parallel. Also, there was again no noticeable difference in the use of one or two plate batteries.

Thus, by using larger filament cells and only one plate battery, the average altitude is more than doubled with a saving of about 5 percent of the total weight of the instrument.

Listening tests at various stations.—In an attempt to determine whether the signals were finally lost due to

insensitivity of the receiver, insufficient range of the transmitter, failure of batteries, or other causes, arrangements were made to have two or more other stations from 10 to 20 miles apart listen to several ascents. In each of these tests, the signals faded rather abruptly at the Massachusetts Institute of Technology. This is indicative of battery failure while the instrument is still within normal range. In every case, the signals faded in the same manner at each of the other stations, and at about the same time, within 5 minutes, which was as close as the clocks could be checked. The other stations, of which there were three in one instance, had receivers as good as or better than that at the Massachusetts Institute of Technology. Their elevations were from 40 to 600 feet above sea level.

It is concluded that the loss of signal was generally due to failure of batteries, rather than to the instrument being carried out of range by high winds aloft, or to an insensitive local receiver. Also, since the batteries had been changed in capacity to run for more than an hour and up to 18 kilometers regularly, freezing rather than power drain is held to be the more probable cause of their failure.

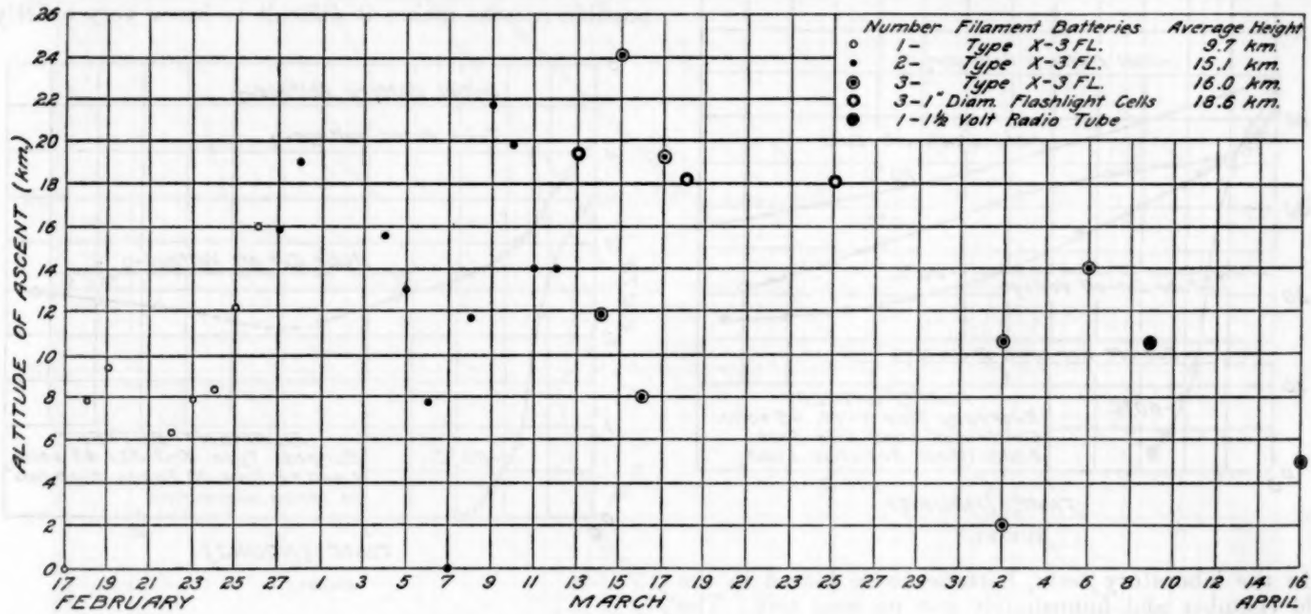
Number Filament Batteries Average Height
1- Type X-3 FL. 9.7 km.
2- Type X-3 FL. 15.1 km.
3- Type X-3 FL. 16.0 km.
3-1" Diam. Flashlight Cells 18.6 km.
1-1½ Volt Radio Tube
ALTITUDE OF ASCENT (km.)
0 2 4 6 8 10 12 14 16 18 20 22 24 26
17 19 21 23 25 27 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 2 4 6 8 10 12 14 16
FEBRUARY
MARCH
APRIL

FIGURE 8.

Subsequent calculations have shown that the ceiling of the balloons is about 20 kilometers, so that further increase of battery capacity would be of little value with this size of balloon. Any slight increase in weight might better be used for insulating or heating the present batteries.

Tests of new type radio tubes.—New tubes now being manufactured have a rated filament voltage of 1.5 volts, which is exactly the terminal voltage of a fresh dry cell. Use of a tube of this type would eliminate the danger of a burnout during flight, with loss of an instrument and record, and would avoid the expense and weight of resistors or series wiring arrangements to reduce the battery voltage.

Several experimental and production models of this 1.5 volt tube were tested in the laboratory and during ascent. Tests for filament cut-off voltage show: For standard 2-volt tubes: (*a*) 2.6 volts, or 58 percent of battery voltage; (*b*) 2.9 volts, or 65 percent of battery voltage. For new 1.5-volt tube (1 sample), 1.2 volts, or 80 percent of battery voltage. It appears, then, that for the same rate of voltage drop, the new type tube will operate for a less time before reaching cut-off voltage, than does the standard type tube. A 1.5 volt tube in which two-tube structures are enclosed in one glass bulb is also available, saving 50 percent of space requirements and about 30 grams weight over the present arrangements of two tubes.

No measurements were made of the power output of the new tubes, but the reduced filament power consumption of the new type indicates that the signal output will be somewhat lower than that of the older type.

One ascent was made with an instrument using one new type two-in-one tube. The altitude reached was 10.7 kilometers, in 58 minutes, when signals were lost due to other than radio faults. Laboratory tests showed the tubes quite capable of operating satisfactorily on the ultra short waves used (68 megacycles).

Use of the radio receiver.—The meteorograph transmitters as received from the maker are all tuned to within about three dial divisions of a fixed point on the receiver dial, when tested before release. As the signal could be heard over a distance of about six divisions of the dial, there was no difficulty in locating it on successive days with different instruments. Upon release, the signal frequency increased as the balloon rose the first few meters above the point of release. This shift was no more than a few dial divisions, and always in the direction of increased frequency. The change was not always noticeable because of the broadness of tuning of the signal when the instrument was close by.

As the instrument continued to rise, the signal weakened somewhat and the tuning sharpened, making it possible to locate the point of strongest signal more exactly. It was then necessary to readjust the tuning only occasionally, to compensate for the further slight increase in frequency caused by the effect of falling temperature on the transmitter.

In general, the sensitivity of the receiver should be adjusted so that only the signal is recorded, and not any interfering electrical disturbances or tube noises. Occa-

sionally, when the signal weakens gradually but persists for a considerable time, it is possible to increase the sensitivity to the point where the recording relay is chattering continuously. If the instrument contacts are constant in length and regular in position, they may then be found among the random extraneous signals more or less readily, thereby increasing the duration of the flight considerably.

Conclusions and recommendations.—Considering maximum life and least weight, the most favorable combination of batteries for the present model of the Harvard meteorograph is believed to be a filament battery consisting of three 1-inch diameter flashlight cells in series and a plate battery consisting of one small 45-volt unit made of Burgess size V cells. Larger batteries or better heat insulation may become necessary when balloons reaching to higher altitudes are used, or when winds aloft have higher than normal velocities.

It is believed that the additional weight of a small amount of insulating material applied to the batteries would be more than compensated for by reduced weight of batteries required, or by much longer life of the present batteries.

Batteries should, in general, be used within a month of receipt from the factory. In no case should batteries of small special sizes be accepted from retailers or other indirect sources. Filament batteries can best be of standard flashlight cell sizes, obtainable fresh from large stores near the point of use, and used within a few days of purchase. Recent types of batteries with layer built cell construction were used during some of these soundings, and were found to lose voltage very rapidly within 2 weeks after their delivery with the instruments. Experience in these tests indicates that about 100 grams per 45-volt unit is the minimum safe weight of a dry battery as now constructed. Tests on batteries which failed on the shelf showed that their failure was probably due to a failure of a single cell, which made the whole battery useless. Improvement must presumably be in the direction of increased uniformity of chemical mixture and assembly technique.

The new 1.5 volt radio tubes are not considered satisfactory for immediate substitution in place of the present 2-volt tubes, due to their reduced power output and shorter period of operation before cut-off, but should be further investigated for possible use in a new design of the radiometeorograph.

FORMATION OF POLAR ANTICYCLONES

By H. WEXLER

[Weather Bureau, Washington, D. C., April 1937]

INTRODUCTION

Meteorologists have known for a long time that when air is cooled from below over a certain area for an extended length of time, an anticyclone forms. The explanation generally given is the following: Cooling of the air, when confined to a restricted area, lowers the isobaric surfaces and so causes a compensating inflow of air from adjacent regions which raises the surface pressure. However, the mechanism governing the compensating inflow and its distribution with height has not been studied carefully. This problem is the subject of the present paper.

Since the cooling over the area is accompanied by a lowering of the isobaric surfaces, that is, by a deepening of a cyclone situated at some level aloft, it seems natural to apply to the problem the Brunt-Douglas [1] theory of the isallobaric velocity component: When a pressure distribution changes with time, the actual wind is composed of two components, viz, the gradient wind, which prevails during stationary, nonfrictional conditions; and an isallobaric component, which blows into the central region of lowering pressure (isallobaric LOW), and is very nearly proportional to the isallobaric gradient. It will be shown that the transport of air across the isobars by the isallobaric component is sufficient to account for the growth of polar anticyclones that is actually observed on weather maps.

Before the isallobaric velocity component can be applied, it is necessary to adopt a cooling model for the atmosphere. In a recent paper by the author,[2] a cooling model was presented for a calm, cloudless, sunless atmosphere possessing, initially, a steep lapse rate and underlain by an unlimited snow surface. From the radiation exchange between the snow surface and the atmosphere, it was possible to determine a relation between the temperature of the snow surface and the maximum free-air temperature. For the snow surface temperature to fall below the value given by this relation, the maximum free-air temperature must decrease; and the cooling process will be one whereby the atmosphere loses energy to space mostly through the spectral band in the black-body radiation from the snow surface to which water vapor is transparent. As the cooling continues, the steep lapse rate decreases until, finally, the atmosphere becomes practically isothermal from above the shallow surface layer of cold air to a height dependent on the initial lapse rate (see fig. 1).

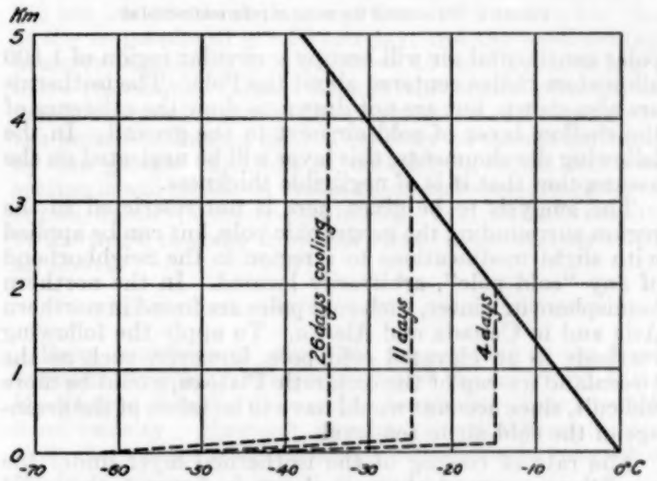

FIGURE 1.—Transformation of polar maritime air into polar continental air.

The cooled air mass is what may properly be called polar continental air, and is found over extensive land and frozen maritime areas in high latitudes during winter. The air above the cooled layer is still characterized by a steep lapse rate, and it also cools by means of radiation directly

[1] Mem. Roy. Met. Soc., Vol. III, No. 22, September 1928.
[2] Mo. WEA. REV., Vol. 64, p. 122, April 1936.

to space; however, it can be shown [2,3] that the cooling of this air is much less than that of the air closer to the surface. In this paper the loss of energy directly to space from the air above the polar continental air will be neglected at first, and later taken into account in a qualitative manner.

Let us now consider the following problem. Assume that the region surrounding the North Pole is a uniform snow field at sea-level and is covered by an extensive air mass of horizontal homogeneity but possessing a vertical temperature gradient of 7.6° C. per kilometer and a surface temperature of 0° C. At the autumnal equinox, the sun is just leaving the Pole; and at the end of 37 days, the region of darkness will have extended to about 1,500 kilometers from the Pole (at about 76° latitude). If during this period 70 percent clear sky has prevailed, then at the Pole the equivalent of 26 days of cooling will have occurred, and at 1,500 kilometers from the Pole there will have been 0 days of cooling. As can be seen from figure 7 of the previous paper,[2] in which it is assumed no heat is transported upward through the snow cover, this cooling will result in a surface temperature of −62° C., and an isothermal layer temperature of −35° C., at the Pole. With the lapse rate we have assumed, the height of the isothermal layer (depth of polar continental air) will be 4.6 kilometers. At 1,500 kilometers from the Pole the depth of the polar continental air will be 0, and, as in figure 2, a wedge of

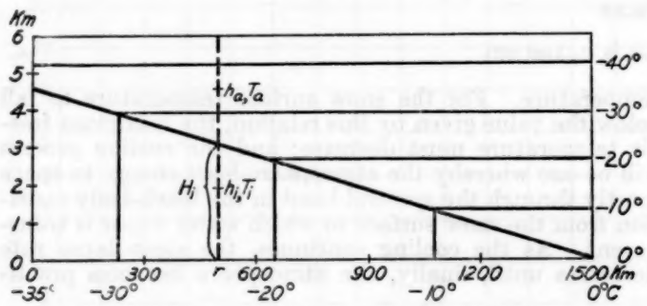

FIGURE 2.—Structure of the wedge of polar continental air.

polar continental air will occupy a circular region of 1,500 kilometers radius centered about the Pole. The isotherms are also shown, but are not drawn to show the existence of the shallow layer of cold air next to the ground. In the following developments, this layer will be neglected on the assumption that it is of negligible thickness.

The analysis to be given here is not restricted to the region surrounding the geographic pole, but can be applied with slight modifications to a region in the neighborhood of any "cold pole", arbitrarily located. In the northern hemisphere in winter, such cold poles are found in northern Asia and in Canada and Alaska. To apply the following methods to an elevated cold pole, however, such as the Greenland ice-cap or the Antarctic Plateau, would be more difficult, since account would have to be taken of the drainage of the cold air to sea-level.

The rate of cooling of the isothermal layer under the conditions assumed above is shown in figure 3 as a solid curve, and is represented analytically by a complicated function of time. However, in order to avoid undue complexities in such an idealized model as adopted here, a linear rate of cooling is assumed, such that in 26 days of cooling, the isothermal layer cools from 0° C. to −35° C; then, if t is the number of seconds of cooling, and T_0 the temperature in °A of the polar continental air, we have

(1) $T_0=273-\beta t$, where $\beta=156\cdot10^{-7}$

The curve plotted from (1) is shown in figure 3 as a dashed line.

Now up to about latitude 72° the recession of the sun southward is very nearly linear with time, and so at any given time the latitudinal temperature distribution will be linear in r, the distance from the Pole. The temperature of the polar continental air at time t, and distance r (in cm.), is given by

(2) $T_t=273-\beta t+\alpha r$, where $\alpha=2.33\cdot10^{-7}$, $\beta=156\cdot10^{-7}$;

t and r are independent variables, but $0\leq r\leq\xi$, $\xi=67\,t$.

COMPUTATION FOR ANTICYCLOGENESIS CAUSED BY CONVERGENCE IN THE POLAR CONTINENTAL AIR

Let us first compute the magnitude of the anticyclogenesis that results from cooling and compensating inflow in the polar continental air alone.

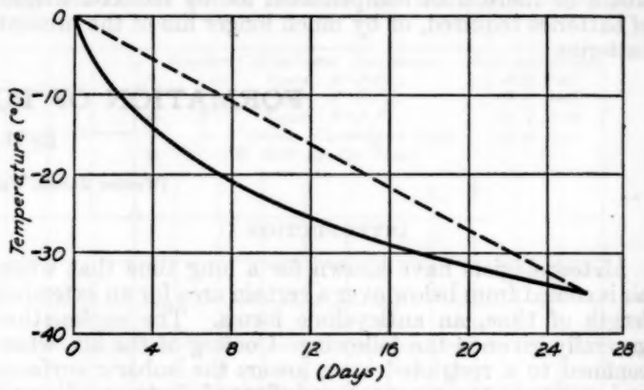

FIGURE 3.—Actual and assumed cooling curves for the isothermal layer (polar continental air).

At a temperature T_t, and at a height h_t above sea level, the pressure in a vertically isothermal atmosphere is given by

(3) $$p_{h_t}=p_0e^{-\frac{mg}{RT_t}h_t}=p_0e^{-\frac{h_t}{H}},$$

where p_0 is the pressure at the surface, assumed to be constant initially; $\frac{R}{m}$ is the gas constant for dry air; g is acceleration due to gravity; and H is the height of the homogeneous atmosphere of surface temperature T_t.

Differentiating with respect to r, and holding p_0 constant, the pressure gradient at height h_t is found to be,

(4) $$\frac{\partial p_{h_t}}{\partial r}=\frac{mgh_t\alpha}{R}\frac{p_{h_t}}{T_t^2}.$$

However, the assumption that p_0 is constant at some stage of the anticyclogenesis is erroneous, since it is the change in p_0 that is desired. Simultaneously with the formation of the cyclone aloft (polar cyclone), the surface anticyclone forms and, as cooling continues, increases in height. If p_0 is held constant, then we assume that the polar cyclone exists at all levels from just above the surface; and we will obtain too great an accumulation of air from inflow, because actually the building-up of the surface anticyclone diminishes the inward transport of

[2] MO. WEA. REV., Vol. 64, p. 122, April 1936.
[3] MO. WEA. REV., Vol. 65, p. 102, March 1937.

air at all heights and really causes an outflow of air in the surface layers. On the other hand, if the variation in p_0 is included in the computations, then a differential equation results which it seems most practicable to solve by a method of successive approximation, as will be shown later: In the first approximation, p_0 is considered constant at 1,000 mb., and the increase of surface pressure found will be too large. Later, when the second approximation is discussed, it will be shown that the maximum difference between the two solutions is less than 24 percent.

Another restriction on the first simple approximation is the assumption of linear flow only. The case of circular flow will be taken up later in this paper.

The geostrophic wind G_i is, from (4),

$$G_i=\frac{1}{\rho_{hi}l}\frac{\partial p_{h_i}}{\partial r}=\frac{gh_i\alpha}{l}\frac{1}{T_i}, \tag{5}$$

where $l=2\Omega\sin\phi$, assumed constant at 1.41×10^{-4}; Ω is the angular velocity of the earth's rotation, ϕ is latitude, and ρ_{h_i} is density at height h_i.

Now the isallobaric velocity component into the deepening Polar Cyclone at height h_i, time t, and distance from Pole r, is found by differentiating (5) with respect to time:

$$\frac{1}{l}\frac{\partial G_i}{\partial t}=\frac{gh_i\alpha\beta}{l^2}\frac{1}{T_i^2}. \tag{6}$$

The transport of mass across the isobars is

$$\frac{\rho_{h_i}}{l}\frac{\partial G_i}{\partial t}=\frac{g\alpha\beta\rho_o}{l^2T_i^2}h_i e^{-h_i/H}\ \text{grm/cm}^2/\text{sec}, \tag{7}$$

where ρ_o is the density at the surface.

The transport reaches a maximum at $h_i=H$; hence, for an atmosphere with zero vertical temperature gradient, but positive horizontal temperature gradient, the mass transport into the central region of cooling attains a maximum at the height of the homogeneous atmosphere corresponding to surface temperature T_i. When $T_i=259°$, $H=7.6$ km.

The total inward transport between the surface and height h_i is

$$I_1=\frac{g\alpha\beta\rho_o}{l^2T_i^2}\int_o^{h_i}h_i e^{-h_i/H}dh_i$$

$$=\frac{p_o\alpha\beta H}{l^2T_i^2}\left[1-\left(1+\frac{h_i}{H}\right)e^{-h_i/H}\right]\text{grm/cm}^2/\text{sec}. \tag{8}$$

If we now consider the flow of air into a cylinder of radius 900 kilometers, whose height, 1.8 kilometers, is that of the polar continental air at that distance from the center, the average increase of surface pressure in mb. for 24 hours is 0.093, which is too small to account for polar anticyclogenesis as actually observed. If, however, the cylinder extends to the top of the atmosphere ($h=\infty$), the average increase in pressure is 3.9 mb./day.

COMPUTATION FOR ANTICYCLOGENESIS CAUSED BY CONVERGENCE IN THE SUPERIOR AIR

If the height of the polar continental air is designated by H_i, then H_i is given by

$$T_i=273-7.6\times10^{-5}H_i. \tag{9}$$

If T_a is the temperature of the superior air at height h_a, then

$$T_a=273-7.6\times10^{-5}h_a.$$

Now the pressure, p_{h_a}, at h_a is given by

$$p_{h_a}=p_o e^{-\frac{mg}{RT_i}H_i}\left(\frac{T_a}{T_i}\right)^{4.5}$$

$$=p_o e^{-4.5\frac{273-T_i}{T_i}}\left(\frac{T_a}{T_i}\right)^{4.5},$$

where T_i alone depends on r.

Then

$$\frac{\partial p_{h_a}}{\partial r}=4.5\alpha p_{h_a}\frac{273-T_i}{T_i^2},$$

and

$$G_a=\frac{1}{l\rho_{h_a}}\frac{\partial p_{h_a}}{\partial r}=\frac{gH_i\alpha}{l}\frac{T_a}{T_i^2}. \tag{10}$$

The isallobaric velocity is

$$\frac{1}{l}\frac{\partial G_a}{\partial t}=\frac{g\alpha\beta10^5}{l^2\,7.6}\left(\frac{2\cdot273-T_i}{T_i^3}\right)T_a; \tag{11}$$

and the transport of air across the isobars is

$$I_a=\frac{\rho_{h_a}}{l}\frac{\partial G_a}{\partial t}=\frac{10^5g\alpha\beta}{7.6\ l^2}\left(\frac{2\cdot273-T_i}{T_i^3}\right)T_a\rho_o e^{-4.5\frac{273-T_i}{T_i}}\left(\frac{T_a}{T_i}\right)^{3.5}; \tag{12}$$

the total transport through a strip of 1 cm. width reaching from the top of the polar continental air to h_a is

$$I_2=\int_{H_i}^{h_a}I_a dh_a=-\frac{10^5}{7.6}\int_{T_i}^{T_a}I_a dT_a \tag{13}$$

$$=\frac{10^5\cdot4.5\alpha\beta}{7.6\cdot5.5\,l^2}p_o(2\cdot273-T_i)\frac{e^{-4.5\frac{273-T_i}{T_i}}}{T_i^2}\left[1-(T_a/T_i)^{5.5}\right]$$

For a circular region of 900 km. radius, the average increase in pressure resulting from convergence in the superior air from 1.8 km. to the top of the atmosphere (36 km.) is 12.40 mb/day, and from 1.8 km. to 8 km. (top of the troposphere) is 8.26 mb/day, and the total average pressure increase is 8.26+0.09=8.35 mb/day, which is a more reasonable value. Almost the entire pressure increase observed is due to the convergence of the air above the polar continental air. This is by no means explained by the greater thickness of this layer; in the following section it will be shown that a much more important factor enters, namely, a many-fold increase in isallobaric velocity at the front, in going from the polar continental air to the air above.

THE ISALLOBARIC VELOCITY DISCONTINUITY

From equations (5) and (10), we see that at the front, between the polar continental air and the air above, where $h_i=H_i$ and $T_a=T_i$, there exists continuity in geostrophic wind velocity. However, as seen from equations (6) and (11), there exists a discontinuity in isallobaric velocity at the front:

$$\frac{1}{l}\frac{\partial G_i}{\partial t}=\frac{g\alpha\beta H_i}{l^2}\frac{}{T_i^2}=\frac{g\alpha\beta}{l^2}\frac{10^5}{7.6}\frac{273-T_i}{T_i^2} \tag{6}$$

$$\frac{1}{l}\frac{\partial G_a}{\partial t}=\frac{g\alpha\beta}{l^2}\frac{10^5}{7.6}\frac{2\cdot273-T_i}{T_i^2}; \tag{11}$$

the ratio of the two velocities is $\frac{2\cdot273-T_i}{273-T_i}$ which is equal

to 9 at the center of the wedge where the front is highest, and is equal to 20 at 900 kilometers from the center where the front is lower.

The explanation of this discontinuity involves a closer examination of the Brunt-Douglas derivation of the isallobaric velocity:

Consider a 2-dimensional system of coordinates, having its X-axis pointing to the east and its Y-axis pointing to the north. The equations of motion for frictionless flow on a restricted portion of the earth's surface are

$$(a) \qquad \frac{du}{dt}=lv-\frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$(b) \qquad \frac{dv}{dt}=-lu-\frac{1}{\rho}\frac{\partial p}{\partial y}.$$

Letting $V=u+iv$ ($i=\sqrt{-1}$), multiplying equation (b) by i, and adding,

$$(c) \qquad \frac{d}{dt}(u+iv)=-\frac{1}{\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)-li(u+iv);$$

solving for $(u+iv)$,

$$(d) \qquad u+iv=\frac{i}{l}\frac{d}{dt}(u+iv)+\frac{i}{\rho l}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)$$

$$=\frac{i}{l\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)+\frac{i}{l}\left(\frac{\partial}{\partial t}+u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}\right)(u+iv).$$

Differentiating the above equation,

$$(e) \qquad \frac{\partial(u+iv)}{\partial t}=\frac{i}{l\rho}\left(\frac{\partial \dot{p}}{\partial x}+i\frac{\partial \dot{p}}{\partial y}\right)+\frac{i}{l}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)\frac{\partial}{\partial t}\left(\frac{1}{\rho}\right)$$

$$+\frac{i}{l}\frac{\partial}{\partial t}\frac{d}{dt}(u+iv),$$

where $\dot{p}=\frac{\partial p}{\partial t}$.

Brunt and Douglas neglect the second term on the right-hand side; but, since in this discussion the density is changing, it is important to retain this term.

From (d),

$$\frac{\partial(u+iv)}{\partial t}=\frac{l}{i}(u+iv)-\frac{1}{\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)-\left(u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}\right)(u+iv);$$

substituting in equation (e) and solving for $(u+iv)$, we find

$$(f) \qquad V=u+iv=\frac{i}{l\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)-\frac{1}{l^2\rho}\left(\frac{\partial \dot{p}}{\partial x}+i\frac{\partial \dot{p}}{\partial y}\right)$$

$$-\frac{1}{l^2}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)\frac{\partial}{\partial t}\left(\frac{1}{\rho}\right)+\frac{i}{l}\left(u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}\right)(u+iv)$$

$$-\frac{1}{l^2}\frac{\partial}{\partial t}\frac{d}{dt}(u+iv).$$

Brunt and Douglas maintain that for atmospheric motion the last term of equation (f) is negligible in comparison with the others, and that for flow not confined to stream-lines of too small radius of curvature, the next-to-last term is also negligible. If these terms are neglected, then equation (f) becomes

$$(f) \qquad V=u+iv=G+I_i+I_\rho,$$

where

$$G=\frac{i}{l\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)=\text{geostrophic velocity},$$

$$I_i=-\frac{1}{l^2\rho}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)=\text{isallobaric velocity},$$

$$I_\rho=-\frac{1}{l^2}\left(\frac{\partial p}{\partial x}+i\frac{\partial p}{\partial y}\right)\frac{\partial}{\partial t}\left(\frac{1}{\rho}\right).$$

In figure 4 these velocities are shown for the polar continental air and the superior air at a point of the front 1.8 km above the ground. The isallobaric velocity in the polar continental air is less than $\frac{1}{10}$ that in the superior air; also, because the density of polar continental air is increasing with time while the reverse is true for the superior air, the quantity I_ρ tends to diminish the isallobaric velocity in the polar continental air, but to increase it in the superior air; hence, the resultant inflow in the lower air is only 0.49 cm/sec., while in the superior air it is 10.05 cm/sec., about 20 times as large.

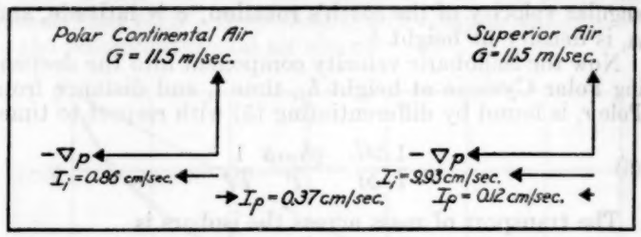

FIGURE 4.—Geostrophic and non-geostrophic velocities at the front (schematic).

The deviation from geostrophic direction in the superior air, caused by the deepening polar cyclone, is about 1:100 and the mass transport of tropospheric air across isobars caused by this slight deviation is sufficient to account for an average increase of pressure of more than 8 mb./day.

It still remains to give a physical explanation of why the isallobaric velocity is 10 times as large in the superior air as in the polar continental air. In order to do this, in figure 5 the pressure tendency profile across the wedge at a height of 1.8 kilometers has been plotted. At the front there appears a discontinuity in the slope of this profile, so that in the superior air it is about 10 times as

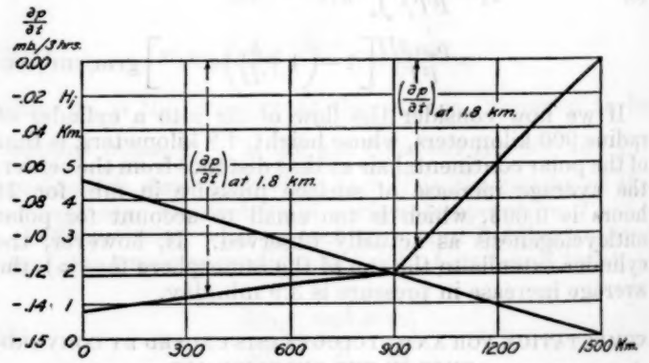

FIGURE 5.—Pressure tendency profile at 1.8 kilometers above the surface.

large as that in the polar continental air. The isallobaric velocity, being proportional to the isallobaric gradient, of course undergoes a similar increase, as already noticed. To explain the discontinuity in isallobaric gradient at the front, imagine that a series of barographs are situated along the wedge at a height of 1.8 kilometers. The barographs in the polar continental air will show almost equal falls, because the sinking of isobaric surfaces is caused mainly by the cooling of the air below 1.8 kilometers.

However, for the barographs situated in the superior air, the only air that is being cooled is the polar continental air which does not reach up to 1.8 kilometers, and so the isobaric surfaces are not sinking as rapidly as in the former case. This becomes more evident as we approach the edge of the polar continental air where the pressure tendency is zero. The discontinuity in the slope of the curve, marking the height of the cooled air which is encountered at 900 kilometers from the Pole, accounts for the discontinuity in the isallobaric gradient, and also for the discontinuity in the isallobaric velocity. To this effect is added that due to the fact that the cooling in the polar continental air increases its density, while the lowering of pressure and the stationary temperature in the superior air decrease its density. These two effects, which combine to give a twentyfold discontinuity in isallobaric velocity at the front, result from the particular cooling model adopted here and illustrated in figures 1 and 2; but the same discontinuity will exist to a less marked degree even if the superior air cools also, provided it does not do so as rapidly as the lower air.

We have previously seen that if the cooling rate is the same at all levels in a vertically isothermal atmosphere, the compensating inflow of air seems too small to account for anticyclogenesis as observed, unless the inflow extends up to the top of the atmosphere. The same would be found true for an atmosphere of steep lapse rate. Hence it appears that in order for polar anticyclogenesis to occur at a rapid rate it is essential that the cooling proceed faster in lower levels than in upper levels.

It now becomes possible to plot the vertical distribution of mass inflow (see fig. 6). From equation (7) it is seen

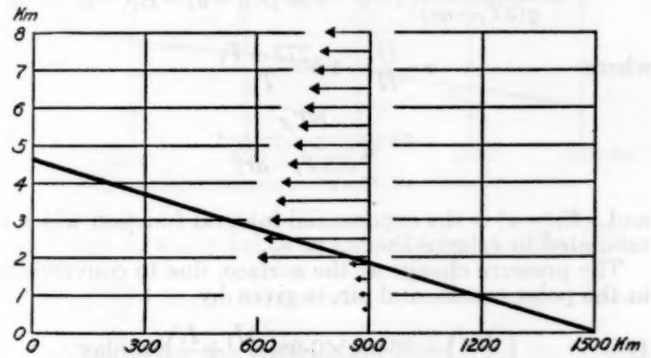

FIGURE 6.—Vertical distribution of mass inflow (arrows shown in the lower air are drawn about 3 times too large).

that the mass transport increases with height until the height of the homogeneous atmosphere is reached (about 7 kilometers). Since the height of the polar continental air is less than this value, the inflow increases with height in the lower air. In the superior air at the front there is about a twenty-fold increase in this inflow, and, as seen from equation (12), the inflow then diminishes with elevation. From equation (13) the ratio of the mass inflow of the superior air, up to various heights, to the total inflow can be found and is shown in table 1.

Since the tropopause is located at about 8 kilometers, the solution found above is valid only up to this height; hence, it can be said that of the total mass inflow occurring between the front (1.8 kilometers) and the tropopause (8 kilometers), about one-half is contained in the 2½ kilometers layer adjacent to the front.

Since anticyclogenesis is occurring at lower levels, in the polar continental air, an outflow really exists in these levels. This decreases with elevation and becomes an inflow at the height corresponding to the line of separation of easterlies from the westerlies.

TABLE 1.—*Ratio of mass inflow of the superior air up to height h_s, and the total inflow*

h_s	T_s	Ratio to total inflow	Ratio to total inflow up to 8 kilometers
1.8 kilometers (at the front)	259	0	0
4	243	.29	.43
6	227	.51	.76
8	212	.67	1.00

COMPUTATION OF THE PRESSURE TENDENCY PROFILE ACROSS AN ANTICYCLONIC WEDGE

If I is the mass of air in grams per second flowing through a strip 1 centimeter wide reaching from the ground to 8 kilometers, then the pressure increase at the ground is given by

$$\frac{\partial p_o}{\partial t}=86400\times 0.98\frac{\partial I}{\partial r}\text{ in mb/day;} \tag{14}$$

where $I=I_1+I_2$, and

$$I_1=\frac{p_o\alpha\beta H}{l^2T_i^2}\left[1-\left(1+\frac{H_i}{H}\right)e^{-H_i/H}\right] \tag{8}$$

$$=\frac{p_o\alpha\beta R/m}{l^2gT_i}\left[1-\left(1+4.5\frac{273-T_i}{T_i}\right)e^{-4.5\frac{273-T_i}{T_i}}\right]$$

$$I_2=\frac{10^5\times 4.5}{7.6\times 5.5}\frac{\alpha\beta}{l^2}p_o(2\times 273-T_i)\frac{e^{-4.5\frac{273-T_i}{T_i}}}{T_i^3}\left[1-\left(\frac{T_a}{T_i}\right)^{5.5}\right] \tag{13}$$

Differentiating (8) and (13) with respect to r, and substituting in (14), the tendency profile across the polar anticyclonic wedge (where the motion is linear) can be found and is shown in figure 7 as the solid curve.

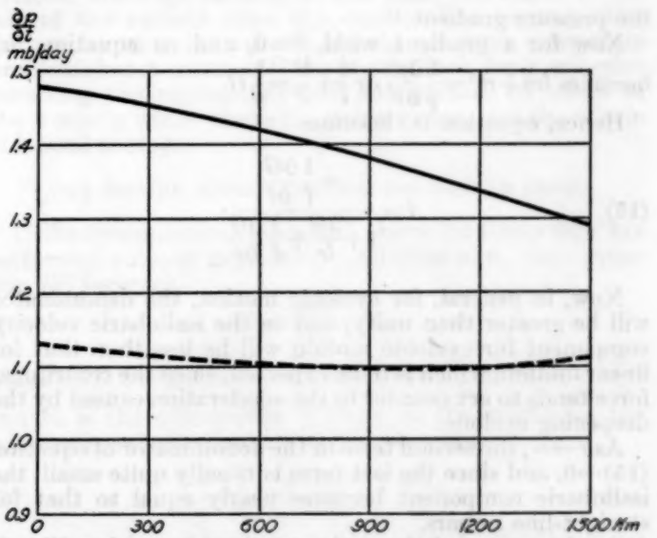

FIGURE 7.—First and second approximations for the pressure tendency profile across the anticyclonic wedge (linear flow).

The pressure changes seem small compared to those observed. However, when a circular anticyclonic area is considered, these turn out to be larger. Before studying this case it is necessary first to compute the isallobaric velocity component for curved motion.

COMPUTATION OF THE PRESSURE TENDENCY PROFILE ACROSS A CIRCULAR ANTICYCLONE

Consider the equations of motion expressed in polar coordinates, (r, θ), where r is the distance of a point from the axis of motion, and θ is the angle of the radius vector, measured counter-clockwise:

$$(a) \qquad \ddot{r}-lr\dot{\theta}-r\dot{\theta}^2=-\frac{1}{\rho}\frac{\partial p}{\partial r},$$

$$(b) \qquad r\ddot{\theta}+2\dot{r}\dot{\theta}+l\dot{r}=-\frac{1}{\rho r}\frac{\partial p}{\partial \theta},$$

where $\dot{r}=\frac{dr}{dt}$, $\dot{\theta}=\frac{d\theta}{dt}$.

Now if the isobars are circular, $\frac{\partial p}{\partial \theta}=0$; therefore,

$$(c) \qquad r\ddot{\theta}+2\dot{r}\dot{\theta}+l\dot{r}=0.$$

Differentiating equation (a) with respect to t, and rearranging terms,

$$(d) \qquad -\dddot{r}+\dot{r}(l\dot{\theta}+\dot{\theta}^2)+r\ddot{\theta}(l+2\dot{\theta})=\frac{d}{dt}\left(\frac{1}{\rho}\frac{\partial p}{\partial r}\right)$$
$$=\frac{\partial}{\partial t}\left(\frac{1}{\rho}\frac{\partial p}{\partial r}\right)+\dot{r}\frac{\partial}{\partial r}\left(\frac{1}{\rho}\frac{\partial p}{\partial r}\right).$$

Assuming $\dddot{r}$ to be negligible in comparison with the remaining terms, eliminating $r\ddot{\theta}$ by means of equation (c), and solving for $\dot{r}$, we find

$$(e) \qquad \dot{r}=\frac{-\frac{1}{l}\frac{\partial G}{\partial t}}{\frac{1}{l}\frac{\partial G}{\partial r}+1+\frac{3\dot{\theta}}{l}+\frac{3\dot{\theta}^2}{l^2}},$$

where $G=\frac{1}{\rho l}\frac{\partial p}{\partial r}$ is the geostrophic wind corresponding to the pressure gradient.

Now for a gradient wind, $\ddot{r}=0$, and so equation (a) becomes $lr\dot{\theta}+r\dot{\theta}^2=\frac{1}{\rho}\frac{\partial p}{\partial r}$, or $\frac{\dot{\theta}}{l}+\frac{\dot{\theta}^2}{l^2}=\frac{1}{rl}G$.

Hence, equation (e) becomes

$$(15) \qquad \dot{r}=\frac{-\frac{1}{l}\frac{\partial G}{\partial t}}{1+\frac{3G}{lr}+\frac{1}{l}\frac{\partial G}{\partial r}}.$$

Now, in general, for cyclonic motion, the denominator will be greater than unity, and so the isallobaric velocity component for cyclonic motion will be less than that for linear motion, which is to be expected, since the centrifugal force tends to act counter to the acceleration caused by the deepening cyclone.

As $r\to\infty$, the second term in the denominator of equation (15)$\to 0$, and since the last term is usually quite small, the isallobaric component becomes nearly equal to that for straight-line isobars.

At the center of the cyclone $\dot{r}$ should vanish. This is seen to be true for motion in the polar continental air. From equation (5)

$$\lim_{r\to 0}\frac{G}{r}=\lim_{r\to 0}\frac{gh_i\alpha}{l}\frac{1}{r(T_o+\alpha r)}=\infty;$$

therefore

$$\lim_{r\to 0}\dot{r}=0.$$

Also, for motion in the superior air, $\dot{r}=0$ at $r=0$, as seen from equation (10),

$$\lim_{r\to 0}\frac{G}{r}=\lim_{r\to 0}\frac{g\alpha T_a}{l}\frac{H_i}{rT_i^2}=\infty, \text{ for } H_i\neq 0;$$

at $H_i=0$, $\lim_{r\to 0}\dot{r}$ has no meaning, so that at the initial instant the limiting process does not hold.

In applying equation (15) to the inflow in the polar continental air, it is necessary to have the following expressions:

$$(5) \qquad G=\frac{gh_i\alpha}{l}\frac{1}{T_i},$$

$$(6) \qquad \frac{1}{l}\frac{\partial G}{\partial t}=\frac{gh_i\alpha\beta}{l^2}\frac{1}{T_i^2},$$

$$\frac{1}{l}\frac{\partial G}{\partial r}=-\frac{gh_i\alpha^2}{l^2}\frac{1}{T_i^2},$$

and so

$$\dot{r}=\frac{-\frac{gh_i\alpha\beta}{l^2}\frac{1}{T_i^2}}{1+\frac{3gh_i\alpha}{l^2T_ir}-\frac{gh_i\alpha^2}{l^2}\frac{1}{T_i^2}}.$$

The mass transport to height H_i is

$$(16) \quad I_1=-\int_o^{H_i}\dot{r}\rho dh_i=\frac{\rho_o g\beta}{l^2T_i^2}\int_o^{H_i}\frac{e^{-h_i/H}h_i dh_i}{1+\left(\frac{3}{r}-\frac{\alpha}{T_i}\right)\frac{gh_i}{l^2T_i}}$$
$$=\frac{p_o\beta r}{g(3T_i-\alpha r)}\{1-e^{-x}+\sigma e^{\sigma}[E_i(-\sigma)-E_i(-(x+\sigma))]\},$$

where

$$x=\frac{H_i}{H}=4.5\frac{273-T_i}{T_i}$$

$$\sigma=\frac{l^2T_ir}{\frac{R}{m}\alpha(3T_i-\alpha r)},$$

and $E_i(-\sigma)$ is the exponential-integral function which is tabulated in Jahnke-Emde,[4] p. 83.

The pressure change at the surface, due to convergence in the polar continental air, is given by

$$(17) \qquad \left(\frac{\partial p_o}{\partial t}\right)_1=86400\times 0.98\left(\frac{\partial I_1}{\partial r}+\frac{I_1}{r}\right)\text{mb/day}.$$

It is easy to show by means of equation (16) that at $r=0$, $\frac{I_1}{r}$ and also $\frac{\partial I_1}{\partial r}$ are finite. The only term where the question of a limit may arise as $r\to 0$ is $\sigma E_i(-\sigma)$. However, as shown by Jahnke-Emde,[4] p. 79, for small values of σ, $E_i(-\sigma)\sim ln\gamma\sigma$, $\gamma=1.78$; hence, neglecting signs,

$$\lim_{r\to 0} ln\gamma\sigma=\lim_{r\to 0}\frac{ln\gamma\sigma}{\frac{1}{\sigma}}$$
$$=\lim_{r\to 0}\frac{\frac{1}{\sigma}}{\frac{1}{\sigma^2}}$$
$$=\lim_{r\to 0}\sigma$$
$$=0$$

[4] Funktionentafeln, B. G. Teubner, Leipzig and Berlin, 1933.

In applying equation (15) to the inflow in the superior air, it is necessary to have the following expressions:

$$(10)\qquad G=\frac{g\alpha T_a H_t}{lT_t^2}=\frac{g\alpha}{l}\frac{10^5}{7.6}\left(\frac{273-T_t}{T_t^2}\right)T_a,$$

$$(11)\qquad \frac{1}{l}\frac{\partial G}{\partial t}=\frac{g\alpha\beta}{l^2}\frac{10^5}{7.6}\left(\frac{2\cdot 273-T_t}{T_t^3}\right)T_a,$$

$$\frac{1}{l}\frac{\partial G}{\partial r}=-\frac{g\alpha^2}{l^2}\frac{10^5}{7.6}\left(\frac{2\cdot 273-T_t}{T_t^3}\right)T_a.$$

Substituting in (15) and integrating the product of $\dot{r}$ and ρ_{h_a} to height h_a, we find

$$(18)\qquad \frac{I_2}{r}=\frac{4.5p_o\beta(2\cdot 273-T_t)e^{-4.5\frac{273-T_t}{T_t}}}{g[3T_t(273-T_t)-\alpha r(2\cdot 273-T_t)]}\int_y^1\frac{y^{4.5}}{y+\eta}\,dy,$$

where $$\eta=\frac{7.6\ l^2T_t^2r}{10^5g\alpha[3T_t(273-T_t)-\alpha r(2\cdot 273-T_t)]},$$

$$y=T_a/T_t.$$

The pressure change at the surface due to convergence in the superior air is given by

$$(19)\qquad \frac{\partial p_o}{\partial t}=86400\cdot 0.98\left[\frac{\partial I_2}{\partial r}+\frac{I_2}{r}\right]mb/day.$$

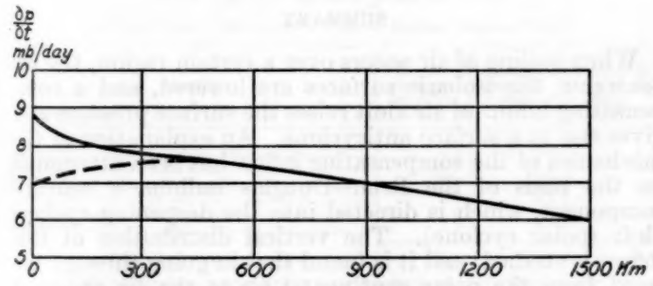

FIGURE 8.—Pressure tendency profile across the circular anticyclone.

In figure 8, the total pressure tendency profile, $\frac{\partial p_o}{\partial t}=\left(\frac{\partial p_o}{\partial t}\right)_1+\left(\frac{\partial p_o}{\partial t}\right)_2$, is plotted as a solid curve, and the profile due to convergence in the superior air, $\left(\frac{\partial p_o}{\partial t}\right)_2$, as the dashed curve, the latter being nearly coincident with the former from about 500 to 1,500 kilometers from the center since in this region the term $\left(\frac{\partial p_o}{\partial t}\right)_1$ is very small, Only near the center does convergence in the polar continental air cause an appreciable pressure rise which when added to the pressure rise due to convergence in the superior air shifts the maximum point of the rise from about 500 kilometers from the center to the center itself. However, if account is taken of anticyclogenesis, the inflow in the polar continental air will be greatly reduced and may even change sign. Hence, the sharp maximum at the center will be reduced and may even be shifted to a position slightly offset from the center.

We have just found that after 26 days of cooling the central increase of pressure in a polar anticyclone is about 8 mb/day. It can be shown that for a younger anticyclone the central increase of pressure is even larger. This increase of pressure, as we have seen, results from the convergence of air aloft into the cooled area. If this were the only process operative, after 26 days of cooling a very intense anticyclone would result having as a central pressure a value never observed. Evidently, there are other factors, of a dynamic nature, involved which prevent such a large accumulation of cold air.

The first of these factors is the increase in westerly winds resulting from the convergence of the superior air toward the center of cooling. The total absolute angular momentum of all the converging rings of air must be maintained and strong westerly winds will be created; the deflective effect of the earth's rotation acting on the rings will be larger than the prevailing pressure gradient, and so there will be a limit to the amount of convergence possible within a given high-level cyclone. To gage the magnitude of the westerly winds created by lateral displacement of rings of air, we may apply the following formula derived under the assumption that each individual ring of air preserves its absolute angular momentum:

$$u=l(r_0-r)$$

where r_0-r is the displacement of an individual ring, assumed small relative to r, the distance from the center; and $l=2\Omega\sin\phi$.

As found above, the convergence of the superior air is about 10 centimeters per second, and so the total displacement for 26 days is about 225 kilometers, creating a westerly wind of about 30 meters per second.

A second factor preventing the creation of large anticyclones is the release of the cold air at certain intervals in the form of an outburst of polar air such as is commonly observed in winter over large portions of the earth's surface. The release of the cold air does not seem to be a simple function of the intensity of the anticyclone or of the pressure gradient; nor is the cold air always galvanized into motion by a wave (young cyclone) moving along the front. Indeed, very often the cold air outbreaks seem to take place in North America without the aid of any cyclone, although usually, in this case, one forms to the left of the current after the outflow has begun. The factors favoring the release of cold air form a separate problem; but it seems as if one should look for a criterion involving the momentum and temperature structure of the westerly winds above the polar wedge, and the effects of lateral mixing.

THE SECOND APPROXIMATION FOR LINEAR FLOW

If the computations described above for linear flow are performed without neglecting variations in p_0, then equation (5) becomes

$$(20)\qquad G_t=\frac{gh_t\alpha}{lT_t}+G_o,$$

where G_0 is the geostrophic velocity at the surface, $\frac{1}{lp_o}\frac{\partial p_o}{\partial r}$, and G_t is the geostrophic velocity at the height h_t; the isallobaric velocity [equation (6)] becomes

$$(21)\qquad \frac{1}{l}\frac{\partial G_t}{\partial t}=\frac{gh_t\alpha\beta}{l^2T_t^2}+\frac{1}{l}\frac{\partial G_o}{\partial t};$$

the mass inflow in the polar continental air [equation (8)] becomes

$$(22)\quad I_1=\frac{p_o}{gl}\left\{\frac{R/m\ \alpha\beta}{lT_t}[1-(1+x)e^{-x}]+[1-e^{-x}]\frac{\partial G_o}{\partial t}\right\}\text{gm/cm/sec},$$

where $x=\frac{H_t}{H}=4.5\frac{273-T_t}{T_t}$.

Likewise in the case of the superior air, equations (10), (11), and (13) become, respectively,

$$G_a=\frac{T_a}{T_i}\left[\frac{g\alpha H_i}{lT_i}+G_o\right], \tag{23}$$

$$\frac{1}{l}\frac{\partial G_a}{\partial t}=\frac{g\alpha\beta}{l^2}\frac{10^5}{7.6}\left(\frac{2{\cdot}273-T_i}{T_i^3}\right)T_a+\frac{T_a}{lT_i}\left(\frac{\partial G_o}{\partial t}+\frac{\beta}{T_i}G_o\right), \tag{24}$$

$$I_2=\frac{10^5 p_o e^{-\frac{H_i}{H}}}{7.6{\cdot}5.5\frac{R}{m}lT_i}\left[1-\left(\frac{T_a}{T_i}\right)^{5.5}\right]\left\{\frac{10^5 g\alpha\beta(2{\cdot}273-T_i)}{7.6\,lT_i}+T_i\frac{\partial G_o}{\partial t}+\beta G_o\right\}\text{gm/cm/sec.} \tag{25}$$

To find the surface pressure distribution at time t, it is necessary to solve the following equation for p_0:

$$\frac{\partial p_o}{\partial t}=0.98\times 86400\frac{\partial I}{\partial r}, \tag{14}$$

where $I=I_1+I_2$, and I_1, I_2 are given by equations (22) and (25).

As can be seen after writing G_0 in terms of p_0, and performing the required differentiations, a partial, nonlinear differential equation in p_0, with variable coefficients, results. The most practicable method of finding a solution appears to be by successive approximations. First, the pressure profile is computed when variations in p_0 (or G_0) are neglected; this can be easily done as shown above. Then the surface geostrophic wind distribution (G_0) is found; and also, by numerical methods, the surface isallobaric velocity distribution $\left(\frac{1}{l}\frac{\partial G_o}{\partial t}\right)$. These latter two quantities are then substituted in equations (22) and (25), resulting in a second approximation for I_1 and I_2. By numerical methods $\frac{\partial I_1}{\partial r}$ and $\frac{\partial I_2}{\partial r}$ are found, and therefore also the second approximation for $\frac{\partial p_o}{\partial t}$. The process may then be repeated to give further approximations. However, because of the limitations in the numerical methods used, only the second approximation for the pressure tendency profile could be found with any assurance; this is shown in figure 7 as the dashed curve. As should be expected, the second approximation shows a smaller increase of pressure; the difference is especially marked at the center of the anticyclone, where the second approximation is about 24 percent smaller than the first, while at the periphery it is only 14 percent smaller. It has not yet been shown mathematically whether the successive approximations converge and, if so, whether the convergence is so rapid that the second solution is sufficiently accurate. It does not seem worth while to spend more time on the mathematical problems involved, since, as pointed out above, the treatment here has neglected certain important dynamical considerations, such as conservation of angular momentum; this omission the author hopes to correct in a later paper.

CONSTANTS OF THE MODEL

26 days of cooling at a rate of 1.35° C./day;
Vertical growth of the polar continental air ~180 meters/day;
Horizontal growth of the polar continental air ~58 km/day;
Slope of the front ~1/300;
Inflow velocity of the superior air ~9 km/day;
Vertical ascent of the superior air ~30 meters/day;
Sinking of the front by contraction of the cooled air ~10 to 20 meters/day.

The superior air undergoes very little vertical displacement as it moves toward the center, since the ascent caused by motion up the frontal surface is almost compensated by the vertical contraction of the lower cooled air. At the same time, of course, the superior air is being transformed into polar continental air at a rate of 180 meters/day vertically; and, likewise, the discontinuity in inflow velocity is raised vertically at the same rate. The comparatively large inward velocities which existed in the superior air before it was transformed into polar continental air will no longer be maintained and will disappear by mixing with the slower moving air.

SUMMARY

When cooling of air occurs over a certain region, the air contracts, the isobaric surfaces are lowered, and a compensating inflow of air aloft raises the surface pressure and gives rise to a surface anticyclone. An explanation of the mechanics of the compensating inflow has been attempted on the basis of the Brunt-Douglas isallobaric velocity component, which is directed into the deepening cyclone aloft (polar cyclone). The vertical distribution of this inflow is studied; and it is found that in going through the front from the polar continental air to the air above, a many-fold increase in isallobaric velocity occurs, showing that almost all the increase in surface pressure results from convergence in the air above the lower cooled air.

At any given time in the life history of the growing polar anticyclone, it is possible to construct surface pressure tendency profiles, and the magnitude of the increases seems to be in satisfactory agreement with those observed on weather maps.

The next step in the problem is to include certain dynamical reasoning omitted in this preliminary treatment and then to explain the release of these large masses of cold air, which occurs in a discontinuous manner, sometimes with no apparent clue in the shapes of surface isobars or in 3- and 12-hour pressure changes.

METEOROLOGICAL ASPECTS OF HAILSTORMS IN NEBRASKA

By G. DAVID KOCH

[Department of Geography, University of Nebraska, Lincoln, Nebr.]

This paper presents the results obtained from an intensive study of the available data on hailstorms in Nebraska, which cover the 13-year period 1924–36, inclusive. These data from the files of the United States Weather Bureau office at Lincoln are the result of observations made by voluntary weather observers at cooperative Weather Bureau stations located in various parts of the State. The reports contain data pertaining to location, width, length, and direction of movement of the individual hailstorms. Each report was carefully checked by the officials of the Weather Bureau and thus obvious errors and superficial estimates were corrected. Few storms are recorded earlier than April or later than September. Even though hail should fall during the late fall and winter months a relatively small amount of damage is done to crops. Hence, only the months April to September, inclusive, are here considered.

Hail occurs only during the passage of a thunderstorm; and records indicate that destructive hail occurs in only a comparatively small number of thunderstorms. Of the

total of 13,996 thunderstorms reported for the 13-year period, only 940 or 6.1 percent were recorded as having been attended by moderately heavy hail. Considering only the 6 months of the year we find the percent of reported thunderstorms accompanied by hail was highest in April and May, and lowest in September.

TABLE 1.—*The total number and percent of thunderstorms attended by hail for the years 1924–36 inclusive*

[Source of data: United States Weather Bureau, Lincoln, Nebr.]

Month	Total number for 13-year period	Total number accompanied by hail	Percentage accompanied by hail
April	1,204	120	9.9
May	1,792	201	11.2
June	4,780	269	5.6
July	2,359	142	6.0
August	2,636	145	5.5
September	1,225	63	5.1
Total	13,996	940	6.1

More hailstorms were formed in frontal thunderstorms than in any other type. Fifty-four and a half percent of the hailstorms occurred in the frontal thunderstorms, 42.4 percent in the heat type, and only 3.1 percent in or near the center of an area of high pressure.

TABLE 2.—*The percent of thunderstorms attended by hail, in relation to the different types of pressure areas*

[Source of data: United States Weather Bureau, Lincoln, Nebr.]

Month	Percent in warm sector of low	Percent of frontal type	Percent in center of high
April	2.2	7.4	0.2
May	10.0	11.7	1.1
June	10.0	17.3	.5
July	7.0	5.1	.8
August	11.0	9.9	.5
September	2.2	3.1	.0
Total	42.4	54.5	3.1

The hours during which the largest number of hailstorms occurred show little relation to the hours of greatest precipitation. Sixty-one percent of the hailstorms took place between the hours of 2 p. m. and 7 p. m., and only 21 percent occurred between 8 p. m. and 6 a. m., whereas during the period 1905–23 at Lincoln, about 34 percent of the total amount of rain fell from 6 a. m. to 6 p. m. and about 66 percent from 6 p. m. to 6 a. m.[1] It is generally accepted that the major portion of summertime rainfall comes as the result of thunderstorms. Kincer[2] found that in a small area centered roughly over eastern Nebraska, 65 percent of the summer rain falls between the hours of 8 p. m. and 8 a. m. With the exception of a small area in southern Arizona the area in Nebraska experienced the highest summer nighttime precipitation in the United States.

TABLE 3.—*The number and percent of hailstorms which occurred during the 24 hours of the day*

[Source of data: United States Weather Bureau, Lincoln, Nebr.]

Hour	Number	Percent	Hour	Number	Percent
6–10 a. m.	9	2.3	5–6 p. m.	44	11.3
10–12 noon	7	1.8	6–7 p. m.	51	13.4
12–1 p. m.	4	1.0	7–8 p. m.	36	9.4
1–2 p. m.	9	2.3	8–9 p. m.	20	5.2
2–3 p. m.	26	6.8	9–10 p. m.	25	6.5
3–4 p. m.	53	13.9	10–12 midnight	18	4.7
4–5 p. m.	58	15.0	12–6 a. m.	20	5.2

Whether more afternoon thunderstorms were actually attended by hail, or whether numerous nighttime hailstorms were not reported, must remain a matter of conjecture, however, until longer and more complete records are available.

Of the 404 hailstorms for which data are available, 78.8 percent came from some westerly direction. The largest number coming from any one direction was 173 or 42.8 percent, from the northwest. The smallest number, 5 or only 1.2 percent, was reported from the east.

TABLE 4.—*Direction of movement of hailstorms in Nebraska, 1923–36, inclusive*

[Source of data: United States Weather Bureau, Lincoln, Nebr.]

Directions from which hailstorms came	Number of storms	Percent of total number of storms	Directions from which hailstorms came	Number of storms	Percent of total number of storms
North	28	6.9	South	5	1.2
Northwest	173	42.8	Southeast	18	4.4
West	63	15.6	East	6	1.5
Southwest	82	20.4	Northeast	29	7.1

[1] Carter, Harry G. Variation in hourly rainfall at Lincoln, Nebr. MO. WEA. REV., April 1924, 52: 208–212.
[2] Kincer, Jos. B. Daytime and nighttime precipitation and their economic significance. MO. WEA. REV., Nov., 1916, 44: 628–633.

THUNDERSTORM FREQUENCIES FOR 6-HOUR PERIODS AT MILES CITY, MONT.

By LOUIS R. JURWITZ

[Weather Bureau, Miles City, Mont., January 1937]

Miles City is about 200 miles east-northeast of the Continental Divide which runs through northwestern Wyoming. The city is on the Yellowstone River, approximately 150 miles from where it enters the Missouri River, and at the junction of the Tongue and the Yellowstone Rivers. The elevation of the Weather Bureau station at Miles City is 2,351 feet. The surrounding region to the north and west is flat with low, rolling swells; to the east, south, and southwest the country is more rugged with hills rising to an elevation of 500 to 800 feet above the valley floor.

Vegetation is sparse except on the hills to the east which are moderately covered with scattered stands of pine. The hills to the south and southwest are bare and of a "badland" character favoring convectional thunderstorms. Fully 75 percent of the thunderstorms which occur at the station have their origin to the south and southwest while the remainder of the convectional type storms move into the valley from the hills that lie to the east.

Thunderstorms are in general of moderate intensity, and as a rule last from 2 to 6 hours, with occasional excessive precipitation and moderate hail.

Figure 1 shows that the majority of thunderstorms occur during June; 94 out of a total of 290 storms recorded in the period 1923–35 occurred during that month. Thunderstorm frequency remains relatively high during the 6-hour period from 6 p. m. to midnight during July and August due to the high evening temperatures prevalent in those 2 months, whereas it falls off rapidly during June. In June, 42 thunderstorms, or 45 percent of the total recorded for that month, occurred between noon and 6 p. m., while for the period from 6 p. m. to midnight a decrease to 34, or 36 percent of the total, is shown.

In July and August, the 6-hour period 6 p. m. to midnight had a higher frequency than the noon to 6 p. m. period. The noon to 6 p. m. period for July had 33 percent of the total number of storms, while the 6 p. m. to midnight period had 36 percent. A greater divergence is noted for August, with the noon to 6 p. m. period having only 20 percent of the total and the 6 p. m. to midnight period 45 percent.

The graphs of the number of thunderstorms recorded for the entire period 1923–35 show for those occurring between noon and 6 p. m. nearly symmetrical ascent and descent on either side of a peak in June, and for those between 6 p. m. and midnight a relatively high peak maintained from June through August.

The 6-hour period from 6 p. m. to midnight shows the highest percentage of thunderstorms, with 37 percent of the total of 290 storms that were recorded; the noon-to-6 p. m. period is a close second, with 35 percent; and the two 6-hour periods from midnight to 6 a. m., and 6 a. m. to noon, show 10 percent each. The times of beginning of 8 percent of the thunderstorms are unknown.

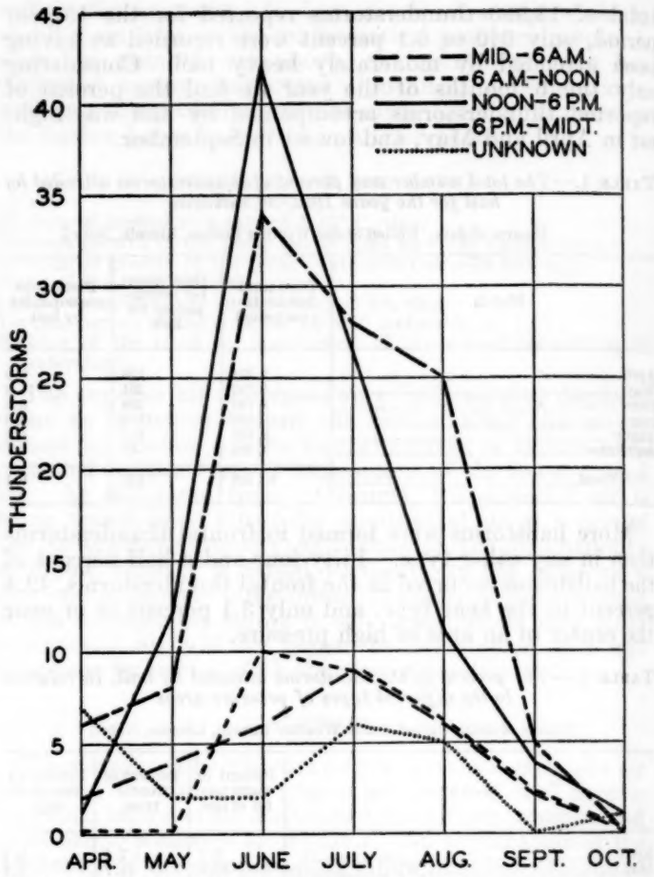

FIGURE 1.—Frequencies of thunderstorms recorded at Miles City, in 6-hour periods, 1923 to 1935, inclusive

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By AMY D. PUTNAM

RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR OBSERVATIONS DURING JUNE 1937

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1935 REVIEW, page 24.

Table 1 shows that solar radiation intensities averaged above normal for June at Washington and Lincoln, and close to normal at Madison.

Through the courtesy of Mr. Marion Eppley of the Eppley Laboratory, Newport, R. I., summaries of total solar and sky radiation received on a horizontal surface at Newport will be included in table 2 beginning with this issue. The instrumental equipment consists of an Eppley thermoelectric pyrheliometer recording on a Leeds and Northrup mixromax potentiometer. The coordinates of the station are as follows: Latitude, 41°30′ N., longitude 71°19′ W., and elevation of the pyrheliometer above sea level, 52 feet.

Table 2 shows an excess in the amount of total solar and sky radiation received on a horizontal surface at Madison, Lincoln, Chicago, New York, and Fresno, and a deficiency at all other stations.

Owing to an intensive program of calibration of a number of pyrheliometers during the month, no turbidity measurements were made.

Polarization observations made at Washington on 5 days give a mean of 57 percent with a maximum of 60 percent on the 24th. At Madison, observations made on 6 days give a mean of 52 percent with a maximum of 62 percent on the 30th. The values for Washington are close to normal, but those for Madison are considerably below the normal for June.

TABLE 1.—*Solar radiation intensities during June 1937*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.				[1]1.0	P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 7	15.65	------	0.48	0.66	0.82	1.16	------	------	------	------	16.79
June 12	12.24	0.71	.78	.87	1.18	------	------	------	------	------	7.87
June 22	13.13	------	------	1.10	1.24	1.48	------	------	------	------	10.59
June 23	9.14	------	1.03	1.16	1.27	1.49	------	------	------	------	8.48
June 24	12.22	------	.58	1.00	1.26	1.45	------	------	------	------	9.83
Means	------	(.71)	.72	.96	1.15	1.40	------	------	------	------	------
Departures	------	+.16	+.04	+.17	+.20	+.15	------	------	------	------	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during June 1937*—Contd

[Gram-calories per minute per square centimeter of normal surface]

MADISON, WIS.

Date	Sun's zenith distance: 8 a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.				1.0	P. M.				Local mean solar time
	e	5.0	4.0	3.0	2.0		2.0	3.0	4.0	5.0	e
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
June 10	6.27	------	------	------	------	1.50	1.27	------	0.88	------	6.27
June 11	7.04	------	------	------	1.22	1.32	------	------	------	------	6.50
June 18	11.38	------	.60	.83	1.08	1.20	------	------	------	------	11.81
June 22	11.38	------	------	------	1.20	1.49	------	------	------	------	11.81
June 24	19.89	------	------	.84	1.03	1.32	------	------	------	------	21.28
June 25	24.31	------	.56	.71	.80	------	------	------	------	------	23.52
June 30	8.48	------	1.06	1.12	1.24	1.50	------	------	------	------	7.57
Means	------	------	.74	.88	1.10	1.39	(1.27)	------	(.88)	------	------
Departures	------	------	−.11	+.09	+.06	+.06	------	------	------	------	------

LINCOLN, NEBR.

June 14	10.59	------	------	------	------	------	1.11	0.87	0.74	0.58	11.38
June 21	17.96	------	0.87	1.02	1.09	1.41	1.12	.96	.86	.73	12.24
June 22	13.13	.75	.82	.93	1.18	1.39	1.03	.80	.63	.48	13.61
June 23	15.65	.73	.88	1.01	1.21	1.40	1.11	.91	.76	.63	10.97
June 24	14.60	------	.23	.32	.56	------	------	------	------	------	14.60
June 30	9.14	------	------	------	------	------	1.17	1.03	.90	.80	8.81
Means	------	(.74)	.70	.82	1.01	1.40	1.11	.91	.76	.64	------
Departures	------	−.02	−.08	−.11	−.11	+.04	.00	−.01	−.01	−.03	------

BLUE HILL, MASS.

June 4	11.1	------	------	------	------	1.20	------	------	------	------	9.8
June 6	11.1	------	------	------	------	1.32	0.94	------	------	------	11.6
June 7	16.4	------	------	------	------	1.07	------	------	------	------	16.6
June 9	11.9	------	------	------	0.96	1.20	------	------	------	------	11.8
June 12	10.3	------	------	0.83	1.08	1.34	1.24	------	------	------	8.8
June 13	9.2	------	------	------	1.05	1.18	1.03	1.09	------	------	7.7
June 15	12.8	------	------	------	.81	1.15	------	------	------	------	14.1
June 16	9.9	------	------	------	1.10	1.23	------	------	------	------	8.0
June 17	10.7	------	------	------	------	1.27	1.01	------	------	------	12.8
June 20	10.7	------	------	------	------	1.30	------	------	------	------	12.1
June 23	9.9	------	------	------	------	1.36	1.06	------	------	------	7.8
June 24	8.8	------	------	.94	1.16	1.43	1.19	1.03	0.89	------	8.5
June 25	10.3	------	------	------	------	1.37	------	------	------	------	9.5
June 29	11.9	------	------	------	------	1.05	1.07	------	------	------	11.6
Means	------	------	------	(0.88)	1.03	1.25	1.08	(1.06)	(.89)	------	------
Departures	------	------	------	−.12	−.04	−.03	.00	+.03	−.01	------	------

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	San Juan	Friday Harbor	Ithaca	Newport
	Gram-calories per square centimeter																
1937	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
June 4	593	544	534	429	489	746	483	638	571	386	399	540	562	652	636	440	494
June 11	447	515	516	417	524	708	432	514	621	460	392	593	563	585	388	447	542
June 18	505	638	695	520	436	753	554	589	613	353	387	621	416	552	407	677	418
June 25	414	646	599	537	408	680	383	631	509	392	413	604	377	595	569	422	428
	Departures from weekly normals																
June 4	+93	+33	−16	−14	+57	+87	+1	+64	.....	−122	−81	−15	+48	.....	+17	−38	.....
June 11	−50	+8	−29	−32	+82	+ 6	−62	−112	.....	−20	−93	−15	+43	.....	−155	−63	.....
June 18	+12	+111	+112	+52	+ 2	+28	+34	−99	.....	−93	−73	−1	−92	.....	+75	+155	.....
June 25	−112	+110	−4	+93	−39	−41	−67	−23	.....	−108	−37	+4	−171	.....	+2	−103	.....
	Accumulated departures on July 1																
	−868	+1,204	−1,218	+702	+3,633	+3,500	+1,561	+154	.....	−5,579	+5,306	−2,394	−889	.....	−910	−1,995	.....

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during June 1937 and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in millimeters, if precipitated*

BLUE HILL OBSERVATORY OF HARVARD UNIVERSITY

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	(*) $\frac{I_y}{.851+C}$	(*) $\frac{I_r}{.840+C}$	$\beta_{m=1}$	$\frac{I_{w=0}}{1.94}$	$\frac{I_{w=0}-I_m}{1.94}$	w	Mass in lower layers	Mass aloft
									Percentage of solar constant			Air-mass type	
1937	° ′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*	*gr. cal.*	*gr. cal.*	*gr. cal.*			*mm.*		
June 4:													
0:32 a	68 47	1.07	1.148	0.890	0.583	1.072	0.714	0.100	77.0	16.1	14.6	NPC/S.	
June 7:													
1:28 p	63 13	1.12	0.992	.643	.502	.782	.615	.152	70.3	17.8	17.0	NP/TA.	
2:39 p	51 14	1.52	.907	.591	.490	.710	.601	.140	65.4	17.3	16.3		
June 9:													
5:05 a	25 18	2.33	.919	.615	.498	.744	.610	.092	70.5	21.7	14.4		
1:45 a	61 04	1.15	1.154	.737	.583	.891	.713	.120	77.2	15.7	14.8	NP/S.	
0:04 a	70 39	1.06	1.183	.724	.591	.876	.724	.092	79.0	16.2	15.0		
June 12:													
3:49 a	34 41	1.56	1.150	.743	.593	.899	.728	.066	81.3	20.4	16.5		
1:41 a	61 47	1.13	1.221	.794	.636	.961	.780	.073	83.3	18.5	17.6	NPC.	
2:49 p	50 34	1.29	1.221	.777	.616	.945	.755	.086	78.9	13.5	12.1		
June 13:													
4:37 a	30 46	1.95	1.070	.682	.557	.830	.684	.081	71.7	14.8	10.7		
3:01 a	48 10	1.34	1.263	.780	.626	.945	.768	.075	76.6	8.4	7.3	NP.	
0:24 a	70 20	1.06	1.341	.820	.660	.997	.810	.094	76.3	5.0	4.9		
3:54 p	37 58	1.62	1.135	.702	.585	.850	.716	.116	67.6	6.9	4.3		
June 15:													
3:52 a	38 46	1.59	.963	.608	.483	.745	.593	.124	64.7	13.5	10.8	NP.	
0:29 p	70 08	1.06	1.126	.658	.553	.827	.679	.100	77.6	17.7	17.4		
June 16:													
3:53 a	38 41	1.60	1.164	.750	.599	.910	.735	.100	68.3	6.3	5.0		
1:52 a	59 36	1.16	1.210	.791	.636	.957	.780	.112	74.3	9.9	8.4	NPC/S.	
1:07 p	66 32	1.09	1.144	.754	.603	.913	.745	.153	71.0	10.1	9.8		
June 17:													
0:44 a	69 04	1.07	1.247	.798	.644	.967	.797	.134	73.2	6.9	6.7	NP/NPM.	
1:10 p	66 11	1.09	1.251	.802	.626	.978	.774	.084	78.9	12.3	10.9		
June 23:													
4:17 p	34 30	1.76	1.195	.770	.607	.935	.751	.055	75.7	11.9	9.1	NPC/NPA.	
June 24:													
4:26 a	32 32	1.86	1.160	.747	.602	.930	.740	.050	74.1	12.5	9.3		
2:58 a	48 40	1.60	1.248	.794	.620	.962	.762	.029	80.5	14.0	11.2		
0:24 p	70 2[illegible]	1.06	1.414	.867	.688	1.052	.845	.050	83.8	8.5	8.3	NPC/NPP.	
2:22 p	54 00	1.24	1.349	.842	.652	1.021	.801	.026	84.7	12.8	11.6		
4:23 p	32 51	1.84	1.200	.776	.600	.942	.737	.033	78.8	14.9	11.1		
June 25:													
0:37 a	69 40	1.06	1.365	.838	.648	1.014	.797	.028	87.1	14.4	14.1	NPC/NPP.	
June 29:													
3:55 p	36 05	1.69	.972	.656	.504	.796	.631	.102	67.9	16.1	12.5	NPA/S.	

* Corrected for transmission of screens and reduced to mean solar distance.

Meteorological Conditions During Solar Observations, Blue Hill Meteorological Observatory, June 1937

Date	Time from local noon	Temperature °C	Wind Beaufort	Visibility	Sky blue	Haze[1]	Cloudiness and remarks
June 4	0:32 a. m.	20.0	WSW 3	7	8	1	6 Cu.
7	0:19 a. m.	22.8	ENE 3	6	7	2	8 Cu.
7	1:28 p. m.	23.1	NE 2	6	7	2	3 Cu.
7	2:43 p. m.	24.4	NE 2	6	7	2	1 Ac, 1 Cunb.
9	5:05 a. m.	16.7	SW 4	8	8	0	Zero clouds.
9[2]	2:07 a. m.	22.8	SW 3	7	8	1	Zero clouds.
9	1:45 a. m.	22.8	SW 3	7	8	1	Zero clouds.
9[2]	0:26 a. m.	25.0	SSW 3	7	8	1	Few Cu.
9	0:04 a. m.	25.6	SSW 3	7	8	1	Few Cl., 1 Cu.
12	3:49 a. m.	18.9	NW 2	7	8	0	Few Cu.
12	1:41 a. m.	22.5	SW 2	8	8	0	Few Cl., Few Cu.
12	2:49 p. m.	24.4	SW 3	8	8	0	4 Cu.
13	4:37 a. m.	17.8	W 4	8	8	0	Few Cl.
13[2]	3:13 a. m.	21.0	W 3	8	8	0	Few Cl.
13	3:01 a. m.	21.0	W 3	8	8	0	Few Cl.
13	0:24 a. m.	23.2	W 5	8	8	0	Few Cl., Few Cu.
13	3:54 p. m.	25.7	WSW 3	9	8	-------	Few Cu.
15	3:52 a. m.	20.3	NW 3	8	8	0	Few Cu.
15	0:29 p. m.	23.1	NNE 2	8	8	1	4 Cu.
16	3:53 a. m.	18.4	ENE 3	9	8	1	Few Cl.
16	1:52 a. m.	20.3	E 3	9	8	0	Few Cl.
16[2]	1:45 a. m.	20.4	E 3	9	8	0	Few Cl.
16	1:07 p. m.	23.2	E 2	9	8	0	2 Cl.
17	0:44 a. m.	21.7	E 2	8	8	1	2 Cl.
17	1:10 p. m.	22.8	SE 2	8	8	1	1 Cl., Few Cu.
23	4:14 p. m.	21.2	SE 1	9	8	0	8 Cl., Few Ac., Few Cu.
24	4:26 a. m.	18.9	NNE 2	6	7	2	Few Cl.
24[2]	3:21 a. m.	21.0	N 2	6	7	2	Few Cl.
24	2:58 a. m.	21.1	NE 3	6	7	2	Few Cl.
24	0:24 p. m.	21.9	NE 3	9	7	0	Few Cl., Few Cu.
24	2:28 p. m.	21.9	NE 3	9	7	0	Few Cl., Few Cu.
24	4:23 p. m.	21.7	NE 3	9	7	0	Few Cl., Few Cu.
29	3:55 p. m.	19.3	NE 3	4	8	0	2 Ci., Few Cu.

[1] Haze—0 Light; 1 Moderate; 2 Dense.
[2] Indicates Smithsonian Observation.

AREAS OF SUNSPOTS MEASURED AT MOUNT WILSON OBSERVATORY

By SETH B. NICHOLSON

[Mount Wilson Observatory, Carnegie Institution of Washington, July 1937]

The areas and positions of sun spots have been published monthly since January 1927 by the U. S. Naval Observatory in the MONTHLY WEATHER REVIEW. The Mount Wilson Observatory of the Carnegie Institution of Washington has cooperated in this program by measuring on the sketches made at the 150-foot tower telescope[1] the areas and positions of sunspots on the days requested by the Naval Observatory. It was early recognized that a large systematic difference existed between the areas so determined and those measured by the Greenwich Observatory, and in 1927 it was found that the areas given in the MONTHLY WEATHER REVIEW had to be increased by 41 percent to eliminate the systematic differences between them and the Greenwich measures.[2] The areas obtained at the Mount Wilson Observatory were apparently in close agreement with those from the Naval Observatory, although very different methods and equipment were used at the two observatories.

The publication of a note in the MONTHLY WEATHER REVIEW for February 1937 to the effect that the areas obtained at the Naval Observatory prior to 1937 should be multiplied by a factor of 1.5708 lead to an investigation of the large systematic differences between the areas determined from visual observations and those obtained from photographs.

Our drawings of sunspots have been made by several different observers, and with one exception all have drawn the spots consistently smaller than shown on photographs; no significant systematic errors were made in their measurement. Areas measured from photographs taken at Mount Wilson agree very closely with those measured at Greenwich, and photographs made with both yellow and blue light give essentially the same areas.

[1] MONTHLY WEATHER REVIEW, *55*, 85, 1927.
[2] Publications of the Astronomical Society of the Pacific, *41*, 277, 1929.

TABLE 1

Year	G./Mt.W.	Weight	G./N.	Weight
1927	1.33	6	0.88	47
1928	1.28	10	.86	71
1929	1.37	9	.88	61
1930	1.47	4	.91	16
1931	1.20	3	1.02	13
1932	1.09	1	.77	8
1933	1.29	1	.87	4
1934	1.19	1	1.18	5
Mean	1.31	----------	.89	----------

The mean factors by which the areas measured on the Mount Wilson drawings have to be multiplied to reduce them to the areas measured on photographs at Greenwich are given for each year in the second column of table 1. The factor to reduce the corrected Naval Observatory measures to the Greenwich scale are in the fourth column. The factor necessary to reduce the Mount Wilson areas to those of the Naval Observatory could not be determined directly, since measurements were made at Mount Wilson only on days for which photographs were lacking at the Naval Observatory. A comparison of both Naval and Mount Wilson Observatories with the Greenwich Observatory indicates that the Mount Wilson areas as published should be multiplied by 0.94 to reduce them to the published areas from the Naval Observatory prior to January 1937 and by 1.48 to reduce them to the corrected areas from the Naval Observatory. The weights in table 1 are proportional to the total areas.

The reason for such a large systematic difference between drawings and photographs probably lies in the fact that the contrast between photosphere and penumbra is reduced on the sketches and increased on the photographs.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U. S. Navy (Ret.), Superintendent, U. S. Naval Observatory. Data furnished by the U. S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. The difference in longitude is measured from the central meridian positive west. The north latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

Date	Eastern standard time	Heliographic			Area		Total area for each day	Observatory
		Diff. in longitude	Longitude	Latitude	Spot	Group		
1937	h. m.	°	°	°				
June 1	11 46	−42.0	349.2	+12.0	-------	776	-------	U. S. Naval.
		+2.0	33.2	−17.0	-------	6	-------	
		+23.0	54.2	+17.0	-------	388	-------	
		+28.0	59.2	+11.0	-------	145	-------	
		+73.0	104.2	+11.0	-------	582	-------	
		+75.0	106.2	+12.0	-------	145	-------	
		+86.0	117.2	−20.0	388	-------	2,430	
June 2	10 57	−82.0	296.4	+10.5	-------	242	-------	Do.
		−69.0	309.4	+9.0	-------	24	-------	
		−29.0	349.4	+12.5	-------	921	-------	
		+12.5	30.9	−18.0	-------	48	-------	
		+36.0	54.4	+17.5	-------	242	-------	
		+41.0	59.4	+13.0	-------	242	1,719	
June 3	14 43	−83.0	280.1	−17.0	194	-------	-------	Do.
		−78.0	285.1	+10.5	-------	242	-------	
		−69.0	294.1	+10.5	-------	339	-------	
		−32.0	331.1	+10.0	-------	24	-------	
		−15.0	348.1	+13.0	-------	1,067	-------	
		+29.0	32.1	−17.0	-------	48	-------	
		+49.5	52.6	+17.5	-------	97	-------	
		+57.0	60.1	+14.5	-------	218	2,229	
June 4	11 5	−70.0	281.9	−16.0	194	-------	-------	Do.
		−64.0	287.9	+11.0	-------	242	-------	
		−56.0	295.9	+11.0	-------	388	-------	
		−40.0	311.9	+10.5	-------	73	-------	
		−11.0	340.9	+9.0	-------	12	-------	
		−2.0	349.9	+13.0	-------	1,067	-------	
		+11.0	2.9	−32.0	-------	24	-------	
		+16.0	7.9	+6.0	-------	12	-------	
		†+40.0	31.9	−17.0	-------	36	-------	
		+65.0	56.9	+17.0	-------	48	-------	
		+74.0	65.9	+14.5	194	-------	2,290	

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Heliographic			Area		Total area for each day	Observatory
		Diff. in longitude	Longitude	Latitude	Spot	Group		
1937	h. m.	°	°	°				
June 5	11 4	−57.0	281.7	−16.0	194			U. S. Naval.
		−50.0	288.7	+11.0		170		
		−42.0	296.7	+10.0		388		
		−26.0	312.7	+10.5		97		
		+2.0	340.7	+9.0	6			
		+11.0	349.7	+12.0		970		
		+21.0	359.7	−32.0		36		
		+30.0	8.7	+6.0		16		
		+52.0	30.7	−18.0		36	1,913	
June 6	12 19	−43.0	281.7	−16.5	194			Do.
		−36.5	288.2	+11.0		170		
		−29.0	295.7	+10.0		388		
		−12.0	312.7	+10.0		48		
		+25.0	349.7	+12.0		776		
		+38.0	2.7	−32.0		48		
		+67.0	31.7	−17.5		145	1,769	
June 7	11 11	−30.0	282.1	−16.5	194			Do.
		−23.0	289.1	+11.0		97		
		−16.0	296.1	+10.0		388		
		−6.0	306.1	−13.0		24		
		−5.0	307.1	−7.0		12		
		+1.0	313.1	+10.0	6			
		+29.0	341.1	+9.0		12		
		+38.0	350.1	+12.0		727		
		+51.0	3.1	−33.0		121		
		+81.0	33.1	−17.5		145	1,726	
June 8	11 2	−17.5	281.5	−16.5	145			Do.
		−10.5	288.5	+11.0		73		
		−3.0	296.0	+10.0		339		
		+50.0	349.0	+13.0		630		
		+63.0	2.0	−33.5		97	1,284	
June 9	11 4	−86.0	199.7	+19.0	97			Do.
		−85.0	200.7	−15.0	97			
		−79.0	206.7	+10.0	485			
		−4.5	281.2	−17.0	194			
		+7.0	292.7	+11.0		339		
		+12.0	297.7	+8.0		48		
		+64.0	349.7	+13.0		630	1,890	
June 10	14 25	−73.0	197.7	+20.5		679		Do.
		−71.0	199.7	−16.0		873		
		−65.0	205.7	+10.0	485			
		−19.0	251.7	+19.5		48		
		+10.5	281.2	−15.0		97		
		+22.0	292.7	+12.0		291		
		+30.0	300.7	+9.0		12		
		+37.0	307.7	−7.0	6			
		+77.0	347.7	+14.0		582	3,073	
June 11	13 30	−70.0	187.9	+21.0		242		Do.
		−60.0	197.9	+20.5		679		
		−59.0	198.9	−16.5		727		
		−51.0	206.9	+9.5	485			
		−7.0	250.9	+19.5		121		
		+3.0	260.9	+21.0		24		
		+24.0	281.9	−16.0		73		
		+35.0	292.9	+13.0		339	2,690	
June 12	11 42	−68.0	177.7	+16.0	6			Do.
		−58.0	187.7	−17.0		145		
		−56.0	189.7	+21.0		242		
		−48.0	197.7	+21.0		630		
		−46.0	199.7	−17.0		679		
		−39.0	206.7	+10.0		679		
		−24.0	221.7	+14.0		24		
		+7.0	252.7	+20.0		97		
		+17.0	262.7	+21.0		242		
		+36.5	282.2	−17.0	24			
		+48.0	293.7	+13.0		339	3,107	
June 13	13 8	−73.0	158.6	+8.0		12		Do.
		−62.0	169.6	+8.0		12		
		−62.0	169.6	−16.0		24		
		−53.0	178.6	+17.0	6			Do.
		−43.0	188.6	−17.0		582		
		−43.0	188.6	+21.0		242		
		−33.0	198.6	+21.0		630		
		−32.0	199.6	−16.0		533		
		−25.0	206.6	+10.0		727		
		+20.0	251.6	+20.0		73		
		+30.0	261.6	+31.0		194		
		+49.0	280.6	−16.0		48		
		+62.0	293.6	+13.0		291	3,374	
June 14	11 3	−88.0	131.6	+10.0	121			Do.
		−62.0	157.6	+8.0		6		
		−50.0	169.6	+8.0		6		
		−48.0	171.6	−16.5		145		
		−41.0	178.6	+15.5	16			
		−35.0	184.6	−19.0		485		
		−31.0	188.6	+20.0		145		
		−29.0	190.6	−16.0		582		
		−22.0	197.6	+21.0		582		
		−15.0	204.6	−15.5		194		
		−12.0	207.6	+9.5	630			
		+13.0	232.6	+34.0		48		
		+30.0	249.6	+20.0		48		
		+43.0	262.6	+21.0		194		
		+75.0	294.6	+13.0	218		3,420	
June 15	11 15	−75.0	131.2	+10.5	485			Do.
		−36.0	170.2	+8.0	12			
		−33.0	173.2	−16.0		242		
		−28.5	177.7	+16.0	16			
		−22.0	184.2	−19.0		388		
		−18.0	188.2	+21.0		97		
		−15.0	191.2	−16.0		727		
		−8.0	198.2	+21.0		582		
		−3.0	203.2	−15.0		194		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Heliographic			Area		Total area for each day	Observatory
		Diff. in longitude	Longitude	Latitude	Spot	Group		
1937	h. m.	°	°	°				
June 15		+1.5	207.7	+10.0		630		U. S. Naval.
		+26.0	232.2	+35.0	24			
		+55.0	261.2	+21.0		242	3,639	
June 16	11 0	−83.0	110.1	−22.0	242			Do.
		−79.0	114.1	+11.0	145			
		−59.0	134.1	+11.0	679			
		−19.0	174.1	−16.0		291		
		−15.0	178.1	+17.0	12			
		−13.0	180.1	+10.0	6			
		−9.5	183.6	−19.0		388		
		−5.0	188.1	+21.0		48		
		−1.0	192.1	−15.5		727		
		+7.0	201.1	+21.0		436		
		+10.0	203.1	−15.0		194		
		+14.0	207.1	+10.0		630		
		+37.0	230.1	+34.0		36		
		+70.0	263.1	+20.0		170	4,004	
June 17	14 40	−68.0	109.9	+11.0		291		Do.
		−68.0	109.9	−23.0	194			
		−44.0	133.9	+11.0		291		
		−4.0	173.9	−15.0		582		
		−1.0	176.9	+16.0	24			
		+1.0	178.9	+10.0	24			
		+6.0	183.9	−19.0		436		
		+12.0	189.9	−14.0		970		
		+21.0	198.9	+21.0		339		
		+24.0	201.9	−15.0		242		
		+30.0	207.9	+10.0		533	3,926	
June 18	12 17	−60.0	105.9	+10.0	97			
		−55.0	110.9	−23.0	339			
		−52.0	113.9	+11.5		339		
		−31.0	134.9	+11.0		727		
		−2.0	163.9	+27.0		24		
		−1.0	164.9	+18.0	24			
		+10.0	175.9	−15.0		485		
		+14.0	179.9	+10.0	12			
		+19.0	184.9	−19.0		339		
		+25.0	190.9	+14.0		970		
		+32.0	197.9	+21.0		339		
		+38.0	203.9	−15.0		242		
		+42.0	207.9	+10.5		533	4,470	
June 19	10 32	−51.0	102.7	−12.0	12			Do.
		−48.0	105.7	+9.5	97			
		−42.0	111.7	−22.5	291			
		−40.0	113.7	+11.0		145		
		−20.0	133.7	+11.0		582		
		+12.0	165.7	+27.0		48		
		+23.0	176.7	−15.0		388		
		+27.0	180.7	+10.0		73		
		+30.0	183.7	−19.0		242		
		+37.0	190.7	−14.0		970		
		+45.0	198.7	+21.0		339		
		+49.0	202.7	−15.0		194		
		+55.0	208.7	+10.0		485	3,866	
June 20	10 48	−35.0	105.3	+10.0		97		Mt. Wilson.
		−31.0	109.3	−22.0	291			
		−29.0	111.3	+11.0		145		
		−7.0	133.3	+12.0		533		
		+27.0	167.3	+27.0		121		
		+37.0	177.3	−16.0		533		
		+41.0	181.3	+10.0		242		
		+45.0	185.3	−20.0		194		
		+50.0	190.3	−15.0		824		
		+61.0	201.3	+20.0		388		
		+69.0	209.3	−16.0		194		
		+71.0	211.3	+9.5		727	4,289	
June 21	11 47	−72.0	54.5	−11.0		291		U. S. Naval.
		−19.0	107.5	+9.0		145		
		−16.5	110.0	−22.0	267			
		−12.0	114.5	+10.0		97		
		+9.0	135.5	−10.0		48		
		+9.0	135.5	+12.0		485		
		+39.0	165.5	+28.0		97		
		+50.0	176.5	−14.0		436		
		+55.0	181.5	+11.0		388		
		+58.0	184.5	−19.0	145			
		+65.0	191.5	−14.0		727		
		+72.0	198.5	+21.0		242		
		+78.0	204.5	−14.0	97			
		+85.0	211.5	+10.0	388		3,853	
June 22	11 2	−75.0	38.7	−18.5		339		Do.
		−60.0	53.7	−12.0		582		
		−15.0	98.7	−13.0		12		
		−7.0	106.7	+9.0		73		
		−4.5	109.2	−22.0	242			
		0.0	113.7	+10.5	97			
		+21.5	135.2	−10.0		97		
		+22.5	136.2	+13.0		582		
		+46.0	159.7	+31.5	12			
		+52.0	165.7	+29.0		97		
		+65.0	178.7	−14.0		582		
		+67.0	180.7	−10.0		388		
		+69.0	182.7	−19.0	145			
		+85.0	198.7	−13.0		339		
		+85.0	198.7	+22.0	97		3,684	
June 23	11 18	−60.0	40.3	−18.5		242		Do.
		−46.0	54.3	−12.5		727		
		0.0	100.3	−13.0		48		
		+7.0	107.3	+9.0		48		
		+9.0	109.3	−23.0	242			
		+12.5	112.8	+10.5	73			
		+20.0	120.3	+21.0		36		
		+35.0	135.3	+13.0		582		

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Heliographic: Diff. in longitude	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day	Observatory
1937	h. m.	°	°	°				
June 23		+38.0	138.3	−10.0	24			U. S. Naval.
		+66.0	166.3	+28.0		97		
		+76.0	176.3	+9.0	194			
		+85.0	185.3	−13.0	582		2,895	
June 24	11 5	−78.0	9.2	+18.0		194		Do.
		−48.0	39.2	−18.5		291		
		−32.0	55.2	−12.5		824		
		−14.0	73.2	+21.0		24		
		−3.0	84.2	+8.0	12			
		+20.5	107.7	−23.0	242			
		+26.0	113.2	+10.0	73			
		+33.0	120.2	+21.0		97		
		+49.0	136.2	+12.0		533		
		+80.0	167.2	+26.0	48		2,338	
June 25	11 14	−62.0	11.9	+19.0		121		Do.
		−35.0	38.9	−18.0	291			
		−19.0	54.9	−12.0		824		
		+33.0	106.9	−23.0	206			
		+39.0	112.9	+10.0	73			
		+44.0	117.9	+21.0		145		
		+62.0	135.9	+13.0		339	1,999	
June 26	10 52	−51.0	9.8	+10.5		48		Do.
		−49.0	11.8	+19.0		97		
		−21.5	39.3	+7.0		24		
		−21.0	39.8	−17.0	194			
		−6.0	54.8	−12.0		582		
		+47.0	107.8	−23.0	194			
		+50.0	110.8	+10.5		73		
		+59.0	119.8	+21.0		194		
		+78.0	138.8	+12.0	242		1,648	
June 27	9 9	−40.5	8.0	+19.0		97		Mt. Wilson.
		−9.5	39.0	+8.0		97		
		−9.0	39.5	−17.0	242			
		+8.0	56.5	−11.0		485		
		+62.0	110.5	−23.0	194			
		+68.0	116.5	+11.0		145		
		+86.0	134.5	+22.0	242		1,502	
June 28	11 11	+3.0	37.2	−17.0		242		U. S. Naval.
		+5.0	39.2	+9.0	16			
		+21.0	55.2	−11.0		485		
		+74.0	108.2	−23.0	194		937	
June 29	11 4	−61.0	320.0	−9.0		24		Do.
		−30.0	351.0	+15.0		73		
		−11.0	10.0	+19.0		48		
		−3.0	18.0	+18.0		48		
		+18.0	39.0	−17.0		194		
		+36.0	57.0	−11.0		218	605	

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard time	Heliographic: Diff. in longitude	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day	Observatory
June 30	10 51	−78.0	289.9	+14.0	97			U. S. Naval.
		−45.5	322.4	−10.0	12			
		−17.0	350.9	+15.0		291		
		+1.0	8.9	+18.0		48		
		+10.0	17.9	+17.0		145		
		+31.0	38.9	−18.0		194		
		+48.0	55.9	−10.0		242	1,029	

Mean daily area for 30 days, 2,587.

PROVISIONAL SUN-SPOT RELATIVE NUMBERS, JUNE 1937

[Dependent along on observations at Zurich and its station at Arosa]

[Furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

June 1937	Relative numbers	June 1937	Relative numbers	June 1937	Relative numbers
1	*Mc* 79	11	96	21	*d* 186
2	*d* 89	12	*MEacc* 134	22	*ad* 199
3	92	13	*Ec* 166	23	*Mac* 163
4	*bd* 116	14	185	24	133
5	*Wc* 128	15	*ad* 191	25	108
6	121	16	*Mabcd* 174	26	116
7	102	17	*b* 190	27	*b* 91
8	*a* 64	18	*a* 194	28	*a* 80
9	*Ecd* 73	19	185	29	*Ec* 80
10	*add* 98	20	*a* 183	30	93

Mean, 30 days = 130.3.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group or spot through the central meridian.
c = New formation of a group developing into a middle-sized or large center of activity; *E*: on the eastern part of the sun's disc, *W*: on the western part, *M*: in the central circle zone.
d = Entrance of a large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

[Aerological Division, D. M. LITTLE, *In Charge*]

By LOYD A. STEVENS

Mean free-air data, based on airplane weather observations during the month of June 1937, are given in tables 1 to 3.

The mean surface temperatures for June (see chart I) were slightly above normal over the greater portion of the country.

The mean free-air temperatures were, for the most part, near normal at all levels. The most consistent negative departures occurred along the Atlantic Coast, where at 5 kilometers departures of minus 2.3° C. and minus 2.5° C. were recorded at Norfolk and Lakehurst, respectively. At Cheyenne negative departures persisted at all levels and at Omaha, also, pronounced negative departures occurred up to 3 kilometers amounting to minus 2.3° C. at 1 kilometer. The greatest positive temperature departure occurred at Seattle, amounting to plus 2.1° C. at 1.5 kilometers. In general the mean free-air temperatures for June averaged from 3° to 4° C. higher at all levels than in May.

The mean free-air relative humidities were above normal at most stations but were below normal at San Antonio up to 2 kilometers (minus 7 percent at 1 and 1.5 kilometers) and at Seattle between 1 and 4 kilometers (minus 9 percent at 2 and 2.5 kilometers). The greatest positive departure (plus 11 percent) occurred at Omaha at all levels between 1 and 2.5 kilometers.

Monthly mean free-air barometric pressures and equivalent potential temperatures are shown in table 3. In general there was an increase in the average pressure, of June over May, of 1 to 2 mb. in the lower levels and of 3 to 5 mb. in the upper levels. The increase was most pronounced at 5 kilometers. The mean isobaric charts as drawn from the values in table 3, were characterized in the lower levels by relatively high pressure over the southeast and extreme northwest portions of the country and a trough of low pressure extending in a NE.–SW. direction across the central part of the country. The mean isobars shifted with altitude, however, and assumed approximately a W.–E. direction across the country above 3 kilometers. In the higher levels a low pressure center was located over Fargo and Sault Ste. Marie. The highest mean pressure was recorded at San Antonio at all levels. Changes in the mean pressure gradient from May to June were relatively unimportant except that there was, in general, decrease in gradient with latitude over the eastern part of the country in the higher levels.

Free-air resultant winds, based on pilot balloon observations made near 5 a. m. (75th meridian time), are shown in table 4. Along the Pacific coast from Oakland northward the resultant winds varied from the normal in a counterclockwise direction (i. e. toward the south) below 3 kilometers. The greatest variation occurred at

Medford at 1.5 kilometers where the current resultant direction was 156° (SSE.) while the normal was 286° (WNW.). The fact that the resultant directions indicated a more southerly origin than normal for the air reaching that part of the country, probably accounted for the above-normal temperatures at Seattle at all levels up to 4 kilometers. At Pensacola the current resultant directions varied from the normal by amounts of 30° to 81° between 2 and 4 kilometers; the variation being in a clockwise direction at 2 and 3 kilometers and in a counterclockwise direction at 2.5 and 4 kilometers. Except in the cases just mentioned, the resultant directions did not vary greatly from the normal. In general the free-air resultant velocities were below normal over the northeast, northwest, and extreme north central portions of the country and above normal elsewhere. At Oklahoma City, however, the departure was negative at all levels up to 3 kilometers. The greatest negative departure (minus 6.0 meters per second) occurred at Fargo at 4 kilometers and the greatest positive departure (plus 3.5 meters per second) occurred at Wright Field at 4 kilometers.

Table 5 shows the maximum free-air wind velocities and their directions for various sections of the United States during June, as determined by pilot balloon observations. The extreme maximum for the month was 47.7 meters per second from the WNW. at 6,975 meters above sea level over Modena, Utah.

The mean monthly equivalent potential temperatures and specific humidities are shown in tables 2 and 3, respectively. The increase in the mean equivalent potential temperatures of June over May amounted to approximately 10° A. at 1 kilometer, 7° at 3 kilometers, and 6° at 5 kilometers. The maximum increase (plus 18° A.) occurred at Murfreesboro at 0.5 kilometer and the minimum (plus 3° A.) occurred at Salt Lake City at 3, 4, and 5 kilometers, respectively. The average increase in the mean specific humidities of June over May was 2 to 3 grams in the lower levels and between 0.2 and 1.4 grams at 5 kilometers. As usual the locations of centers of the highest and lowest specific humidities and equivalent potential temperatures agreed closely with those of highest and lowest mean pressures.

The weather for the month was characterized by considerable activity in that a rather large number of P_c and P_p air masses, for this time of the year, passed across the country. There were several outbreaks of P_p and N_{PP} air from the semi-permanent North Pacific HIGH which usually passed inland at some point along the northern portion of the Pacific coast. Between these relatively cold air masses "LOWS" were formed with well-developed fronts along which relatively heavy precipitation occurred. The frequent passage of such fronts over the north and central Pacific coast area accounted for the above-normal precipitation which occurred there. Over the remainder of the country most of the precipitation which occurred was associated with thunderstorms and was therefore very unevenly distributed. The excess precipitation which occurred over certain portions of New Mexico, for example, resulted from cold-front thunderstorms brought about by certain P_p air masses, which moved farther south than usual and caused sharp temperature differences when they met T_M and S air over that area. Southeastward moving cold P_c air masses combined with T_A and T_M air circulating around the western edge of the Atlantic HIGH to cause above-normal precipitation in the Ohio valley and along the Atlantic coast. The advance of the P_c air masses from the northwest together with the recession of the Atlantic HIGH resulted frequently in the formation of low pressure troughs with well developed cold fronts along which numerous severe thunderstorms occurred.

TABLE 1.—*Mean free-air temperatures (t), °C obtained by airplanes during June 1937. (Dep. represents departure from "normal" temperature.)*

Station	Number of obs.	Altitude (meters) m. s. l.																	
		Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
		t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.
Barksdale Field [1] (Shreveport), La. (52 m)	30	23.6	+0.5	24.5	0.0	21.7	0.0	18.7	−0.2	15.8	−0.4	12.8	−0.6	9.9	−0.5	4.4	+0.1	−2.4	+0.2
Billings, Mont.[2] (1,089 m)	30	14.4	+0.2					16.5	+0.3	13.8	+0.3	10.2	+0.3	6.5	+0.4	−0.5	+0.5	−6.5	+1.3
Boston, Mass.[1] (5 m)	27	16.1		16.4		14.1		11.3		8.3		5.9		4.1		−0.7		−7.6	
Cheyenne, Wyo.[2] (1,873 m)	29	11.4	−0.2							12.7	−0.3	11.3	−1.2	8.0	−1.4	0.5	−1.4	−7.6	−1.3
Coco Solo, C. Z.[3] (15 m)	22	25.3		23.8		21.2		18.6		16.0		14.0		11.3		4.8		−1.2	
El Paso, Tex.[2] (1,194 m)	30	22.3						24.6		22.0		18.5		14.5		6.2		−1.2	
Fargo, N. Dak.[2] (274 m)	29	12.7	−0.5	16.7	+0.9	15.1	+0.7	12.0	+0.3	8.5	−0.4	5.6	−0.3	2.6	−0.4	−2.6	+0.1	−8.8	+3.2
Kelly Field (San Antonio), Tex.[1] (206 m)	26	24.1	+1.0	23.4	0.0	22.2	+0.3	19.9	+0.5	16.8	−0.1	13.9	−0.4	11.1	−0.3	4.9	+0.3	−1.7	+0.5
Lakehurst, N. J.[3] (39 m)	24	16.5	−1.2	19.3	+0.2	17.3	−0.1	13.9	−0.6	10.4	−1.1	7.5	−1.5	4.5	−1.9	−1.0	−2.4	−6.2	−2.5
Maxwell Field (Montgomery), Ala.[1] (52 m)	30	23.5	+0.9	24.1	+0.2	21.8	+0.4	18.4	+0.5	14.9	+0.4	11.9	+0.5	9.2	+0.5	3.4	+0.6	−2.4	+0.7
Miami, Fla.[3] (4 m)	29	22.9		22.8		19.3		15.5		13.2		10.5		8.1		2.7		−3.0	
Mitchel Field (Hempstead, L. I.), N. Y.[1] (29 m)	29	17.2	+0.6	18.0	+0.2	16.5	+0.6	13.8	+0.5	10.9	+0.4	8.0	+0.1	5.4	0.0	0.0	+0.1		
Murfreesboro, Tenn.[2] (174 m)	30	20.4	+0.7	22.5	+0.3	20.6	+0.3	16.9	−0.1	13.9	−0.1	10.8	−0.3	7.9	−0.4	2.2	−0.1	−3.8	−0.1
Norfolk, Va.[3] (10 m)	23	21.2	−1.2	21.1	−0.4	18.1	−1.2	14.7	−1.5	11.5	−1.7	8.5	−1.8	5.6	−2.2	−0.2	−2.2	−5.5	−2.3
Oakland, Calif.[3] (2 m)	30	14.8		15.3		16.5		15.4		12.9		10.1		7.1		1.2		−5.0	
Oklahoma City, Okla.[2] (391 m)	30	22.1	+1.1	23.3	+1.2	22.3	+0.7	19.7	+0.5	16.7	+0.1	13.2	−0.3	10.0	−0.2	3.0	+0.1	−3.9	+0.2
Omaha, Nebr.[2] (300 m)	30	18.0	−0.6	18.9	−1.0	17.9	−2.3	16.1	−1.8	13.6	−1.4	10.6	−1.0	7.7	−0.5	1.7	+0.1	−4.2	+0.9
Pearl Harbor, T. H.[3] (6 m)	30	22.7	−2.0	20.7	−1.0	17.3	−0.9	14.5	−1.0	13.6	+0.1	12.9	+0.8	11.2	+0.7	6.7	+0.2	1.3	0.0
Pensacola, Fla.[3] (13 m)	29	23.2	−1.4	23.5	+0.2	20.4	−0.1	17.2	−0.4	14.1	−0.6	11.7	−0.2	8.9	−0.1	3.3	0.0	−2.2	+0.3
St. Thomas, V. I.[3] (8 m)	30	28.1		23.9		20.0		17.4		15.5		13.6		11.0		4.8		−1.4	
Salt Lake City, Utah [2] (1,288 m)	30	14.1						17.3		15.2		11.8		8.3		0.9		−5.9	
San Diego, Calif.[3] (10 m)	29	18.2	−0.8	15.4	−0.5	18.9	+1.4	18.8	+1.0	17.5	+0.4	15.0	+0.5	12.2	+0.5	6.2	+0.7	−0.7	+0.7
Sault Ste. Marie, Mich.[3] (221 m)	30	10.7		14.6		13.5		10.7		7.6		5.1		2.6		−2.6		−8.8	
Scott Field (Belleville), Ill.[1] (135 m)	23	18.7	+1.1	21.6	+0.7	19.3	0.0	16.8	+0.2	14.2	+0.4	11.9	+0.9	9.1	+0.8	3.3	+0.9	−3.0	+0.8
Seattle, Wash.[3] (10 m)	23	12.5	−1.7	13.1	+0.7	12.2	+1.8	9.9	+2.1	7.1	+1.9	4.5	+1.6	1.8	+1.3	−3.9	+0.6	−10.7	−0.4
Selfridge Field (Mount Clemens), Mich.[1] (177 m)	28	15.3	+0.8	16.8	+0.4	14.6	+0.1	12.2	+0.5	9.8	+0.7	7.4	+0.8	4.5	+0.6	−1.1	+0.8	−7.0	+1.0
Spokane, Wash.[2] (596 m)	30	13.2				16.5		14.2		10.7		7.1		3.4		−3.7		−10.6	
Washington, D. C.[3] (13 m)	30	20.7	−0.5	20.6	+0.5	17.8	−0.2	14.4	−0.8	10.9	−1.5	8.1	−1.5	5.1	−1.8	−0.4	−1.1	−5.6	−0.6
Wright Field (Dayton), Ohio [1] (244 m)	27	16.9	+0.9	18.5	+0.1	17.4	0.0	14.8	+0.2	12.2	+0.4	9.4	+0.2	6.7	+0.3	0.8	+0.3	−5.6	+0.1

[1] Army. [2] Weather Bureau. [3] Navy.

Observations taken about 4 a. m., 75th Meridian Time, except by Navy stations along the Pacific coast and Hawaii where they are taken at dawn.

NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parentheses following the number of observations): Barksdale, 76 (3); Billings, 89 (3); Cheyenne, 89 (3); Fargo, 89 (3); Kelly Field 80 (3); Lakehurst, 71 (3); Maxwell Field, 88 (3); Mitchel Field, 81 (3); Murfreesboro, 90 (3); Norfolk, 184 (9); Oklahoma City, 90 (3); Omaha, 180 (6); Pearl Harbor, 160 (7); Pensacola, 246 (10); San Diego, 210 (9); Scott Field, 82 (3); Seattle, 69 (3); Selfridge Field, 85 (3); Washington, 240 (11); Wright Field, 79 (3).

TABLE 2.—*Mean free-air relative humidities (R. H.), in percent, and specific humidities (q), in grams/kilogram, obtained by airplanes during June 1937. (Dep. represents departure from "normal" relative humidity.)*

Stations	Number of observations	Altitude (meters) m. s. l.																											
		Surface			500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.	
			Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.
Barksdale Field, La	30	15.7	86	+3	13.3	66	+2	11.9	66	+3	10.4	66	+6	8.2	59	+7	6.2	51	+6	4.9	46	+6	3.3	39	0	2.3	39	+2
Billings, Mont	30	7.4	64	0							7.4	53	+2	6.5	53	+3	5.8	56	+2	4.9	58	0	3.7	63	+2	2.6	61	+5
Boston, Mass	27	9.5	83		8.1	66		7.3	65		7.0	71		6.4	74		5.3	68		4.2	58		2.7	47		1.6	41	
Cheyenne, Wyo	29	7.5	72	−1										7.5	65	0	6.4	58	+6	5.3	56	+7	3.6	56	+6	2.3	58	+5
Coco Solo, C. Z	22	18.9	94		17.0	87		15.1	86		14.0	88		11.7	82		9.1	69		7.8	65		5.8	69		4.7	74	
El Paso, Tex	30	7.3	38								8.7	38		7.6	37		6.6	38		6.0	41		4.5	49		3.2	50	
Fargo, N. Dak	29	8.0	85	+5	7.8	62	−2	6.9	58	0	6.0	58	0	5.1	49	+2	4.3	56	−1	3.8	58	+2	2.8	50	+2	1.6	45	+1
Kelly Field, Tex	26	16.2	85	−5	15.7	83	−1	11.9	64	−7	10.2	60	−7	8.7	59	−1	7.3	56	+2	5.8	51	+2	4.0	47	0	2.4	40	−2
Lakehurst, N. J	24	10.5	90	+7	9.0	61	−2	7.6	55	−2	6.9	59	0	6.4	64	+3	5.7	66	+6	4.8	65	+9	3.5	59	+10	2.1	47	+6
Maxwell Field, Ala	30	15.4	86	+2	12.7	65	+2	11.1	61	+2	10.1	65	+3	8.9	66	+5	7.0	60	+3	5.8	56	+4	4.0	52	+5	2.9	49	+7
Miami, Fla	29	15.6	90		14.8	82		12.0	78		9.2	71		7.9	67		6.7	64		5.7	59		4.2	56		3.3	57	
Mitchel Field, N. Y	29	10.6	87	−2	10.3	76	+1	9.9	76	+1	9.2	80	+1	8.0	78	+4	6.9	76	+6	5.5	70	+4	3.9	61	−1			
Murfreesboro, Tenn	30	13.7	90	+10	12.3	69	+5	11.2	67	+4	10.0	71	+5	8.0	64	0	6.0	56	−2	4.7	50	−2	3.1	43	−4	2.1	42	−2
Norfolk, Va	23	13.6	86	+8	11.0	67	0	9.5	66	+3	8.6	70	+7	7.2	68	+6	5.8	63	+4	4.9	59	+4	3.1	52	0	2.0	46	+1
Oakland, Calif	30	8.8	84		9.1	80		8.3	64		6.8	52		5.9	46		4.4	43		3.7	41		2.8	42		2.0	43	
Oklahoma City, Okla	30	13.8	80	+1	13.9	74	+1	12.9	69	+5	11.4	66	+5	9.9	66	+8	8.4	66	+11	6.6	60	+8	4.4	58	+6	2.8	52	+2
Omaha, Nebr	30	11.0	83	+3	10.7	74	+4	9.7	68	+11	8.8	65	+11	7.8	64	+11	6.9	65	+11	5.7	61	+8	4.0	58	+8	2.6	49	+5
Pearl Harbor, T. H	30	13.6	80	+8	12.7	80	+3	11.9	87	+5	10.2	84	+6	7.6	62	−6	4.9	40	−12	3.4	29	−10	2.1	21	−2	1.1	17	−4
Pensacola, Fla	29	16.3	92	+10	14.5	76	+1	12.2	73	+3	10.7	74	+7	9.0	73	+9	7.4	65	+6	6.5	65	+10	4.7	61	+11	2.6	45	+2
St. Thomas, V. I	30	17.6	75		16.6	86		14.7	90		11.8	81		9.0	66		6.6	52		5.0	43		3.5	42		2.7	41	
Salt Lake City, Utah	30	6.8	58								7.1	49		6.1	45		5.3	46		4.7	48		3.6	55		2.7	57	
San Diego, Calif	29	10.3	80	+6	9.5	83	+3	8.5	56	−2	6.4	40	0	4.9	31	+4	4.0	28	+5	3.2	27	+7	2.5	26	+7	1.6	25	+6
Sault Ste. Marie, Mich	30	7.3	89		7.3	66		6.8	63		6.5	68		5.8	70		4.9	67		4.2	65		3.0	58		2.0	54	
Scott Field, Ill	23	12.2	90	+5	11.0	65	+3	10.3	66	+5	9.2	66	+5	8.0	63	+3	6.4	55	−2	5.3	52	−2	3.7	49	0	2.5	45	+2
Seattle, Wash	23	7.6	85	+9	7.2	72	0	6.2	63	−6	5.4	60	−8	4.5	57	−9	3.6	51	−9	3.0	49	−7	2.0	43	−5	1.2	41	0
Selfridge Field, Mich	28	9.4	85	0	8.2	65	+1	7.8	67	+4	6.6	63	0	5.5	58	−2	4.8	56	0	4.0	55	+2	2.8	50	+5	1.7	39	0
Spokane, Wash	30	7.7	76					7.8	59		7.0	58		6.2	61		5.5	65		4.7	68		3.0	66		1.8	60	
Washington, D. C	30	13.0	86	+13	10.8	68	+5	9.3	66	+6	8.3	69	+9	7.3	71	+10	5.8	65	+8	5.0	65	+11	3.4	57	+10	2.2	44	+7
Wright Field, Ohio	27	10.9	89	+4	10.6	76	+5	9.6	69	+4	8.0	64	0	6.5	59	−1	5.4	55	0	4.5	52	0	3.1	50	0	2.4	51	+3

TABLE 3.—*Mean free-air barometric pressures (P), in mb, and equivalent potential temperatures (θ_E), in °A. obtained by airplanes during June 1937*

Station	Number of observations	Altitude (meters) m. s. l.																	
		Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
		P	θ_E	P	θ_E	P	θ_E	P	θ_E	P	θ_E	P	θ_E	P	θ_E	P	θ_E	P	θ_E
Barksdale Field, La	30	1,008	340	957	340	904	338	852	336	804	332	757	329	713	327	631	327	557	328
Billings, Mont	30	892	318					850	325	801	325	754	325	710	323	628	323	554	325
Boston, Mass	27	1,012	314	955	316	900	317	848	318	799	319	751	319	707	319	624	320	552	320
Cheyenne, Wyo	29	813	324							802	327	754	328	710	327	627	325	554	322
Coco Solo, C. Z	22	1,009	351	952	350	900	347	849	347	800	343	754	339	711	338	629	336	557	337
El Paso, Tex	30	880	329					849	339	802	338	756	337	713	336	633	333	560	332
Fargo, N. Dak	29	980	310	955	316	900	317	849	316	799	316	752	316	707	316	623	318	549	320
Kelly Field, Tex	26	992	344	961	345	908	338	857	336	809	334	762	332	718	330	637	330	565	328
Lakehurst, N. J	24	1,009	318	956	322	902	321	851	321	802	321	756	322	712	321	629	322	555	323
Maxwell Field, Ala	30	1,008	330	958	337	906	336	854	335	806	333	758	330	715	329	633	328	559	329
Miami, Fla	29	1,015	339	960	341	906	336	855	329	806	328	758	327	714	328	632	328	558	330
Mitchel Field, N. Y	29	1,010	319	956	324	903	327	851	328	802	326	755	325	710	324	628	325		
Murfreesboro, Tenn	30	994	332	958	335	905	335	854	333	805	329	757	326	714	324	632	324	558	326
Norfolk, Va	23	1,012	331	956	330	902	327	851	327	802	324	754	323	711	322	628	322	554	324
Oakland, Calif	30	1,015	311	957	317	903	322	852	322	803	320	756	320	712	321	629	323	556	324
Oklahoma City, Okla	30	968	338	956	340	903	342	852	340	804	338	757	335	714	333	633	329	559	328
Omaha, Nebr	30	979	323	956	326	903	328	852	329	803	329	756	328	712	327	629	327	556	327
Pearl Harbor, T. H	30	1,017	332	962	333	908	332	856	330	808	328	761	324	718	323	637	325	564	327
Pensacola, Fla	29	1,015	340	960	341	906	337	854	335	805	333	757	331	713	331	631	330	561	328
St. Thomas, V. I	30	1,019	350	965	348	910	343	858	338	810	334	763	330	719	328	637	328	563	330
Salt Lake City, Utah	30	870	319					849	326	800	326	754	326	710	325	628	325	554	326
San Diego, Calif	29	1,013	319	956	318	902	326	850	325	802	324	756	325	712	325	632	327	558	328
Sault Ste. Marie, Mich	30	987	305	956	312	901	315	848	317	799	316	751	317	706	318	623	320	549	321
Scott Field, Ill	23	999	325	959	330	905	330	854	330	805	329	758	328	715	327	633	327	559	328
Seattle, Wash	23	1,016	305	958	310	902	311	849	313	800	312	752	313	707	313	624	315	548	316
Selfridge Field, Mich	28	992	315	956	317	902	319	850	318	801	318	753	319	709	319	626	320	552	321
Spokane, Wash	30	945	313			902	321	851	322	802	321	754	320	710	320	626	318	552	317
Washington, D. C	30	1,014	328	957	328	902	327	850	326	801	324	754	323	709	323	626	322	553	325
Wright Field, Ohio	27	985	321	956	326	902	327	851	325	801	324	755	323	711	322	629	323	555	325

LATE REPORT

TABLE 1.—*Mean free-air temperatures (t), °C. obtained by airplanes during April 1937. (Dep. represents departure from "normal" temperature.)*

Stations	Number of observations	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
		t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.	t	Dep.
Pearl Harbor, Territory of Hawaii[1] (6 m)	30	21.0	−0.8	19.5	−0.2	16.0	−0.3	13.3	−0.3	12.0	+0.1	10.4	−0.2	8.6	−0.2	3.9	−0.5	−2.0	−0.2

[1] Navy.
Observations taken at dawn.
NOTE.—The departures are based on normals covering the following total number of observations made during the same month in previous years, including the current month (years of record are given in parentheses following the number of observations): Pearl Harbor, 108 (4).

LATE REPORT

TABLE 2.—*Mean free-air relative humidities (R. H.), in percent, and specific humidities (q), in grams/kilogram, obtained by airplanes during April 1937. (Dep. represents departure from "normal" relative humidity)*

Station	Number of observations	Surface			500			1,000			1,500			2,000			2,500			3,000			4,000			5,000		
		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.		q	R. H.	
			Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.		Mean	Dep.
Pearl Harbor, Territory of Hawaii	30	12.6	82	+8	11.8	80	+4	10.9	87	+7	9.4	84	+6	6.9	63	−5	4.8	46	−7	3.6	37	−7	2.3	29	−2	1.5	27	−2

LATE REPORT

TABLE 3.—*Mean free-air barometric pressures (P), in mb, and equivalent potential temperatures (θ_E,) in °A. obtained by airplanes during April 1937*

Station	Number of observations	Surface		500		1,000		1,500		2,000		2,500		3,000		4,000		5,000	
		P	θ_a	P	θ_a	P	θ_a	P	θ_a	P	θ_a	P	θ_a	P	θ_a	P	θ_a	P	θ_a
Pearl Harbor, Territory of Hawaii	30	1,016	328	960	329	906	329	854	327	804	324	757	322	712	322	631	324	557	326

TABLE 4.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 5 a. m. (E. S. T.) during June 1937*
[Wind from N. = 360°, E. = 90°, etc.]

Altitude (meters) m. s. l.	Albuquerque, N. Mex. (1,554 m)		Atlanta, Ga. (309 m)		Billings, Mont. (1,088 m)		Boston, Mass. (15 m)		Cheyenne, Wyo. (1,873 m)		Chicago, Ill. (192 m)		Cincinnati, Ohio (153 m)		Detroit, Mich. (204 m)		Fargo, N. Dak. (274 m)		Houston, Tex. (21 m)		Key West, Fla. (11 m)		Medford, Oreg. (410 m)		Murfreesboro, Tenn. (180 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	346	2.2	272	1.1	302	2.7	351	1.3	266	2.9	343	0.3	325	0.6	285	1.0	160	0.5	202	0.6	137	1.9	324	0.7	202	0.7
500	-----	-----	270	3.8	-----	-----	353	3.2	-----	-----	236	.8	280	1.9	301	1.8	179	2.2	190	7.4	130	3.6	306	0.5	244	2.2
1,000	-----	-----	276	3.9	-----	-----	330	3.2	-----	-----	288	2.6	282	4.8	293	4.1	243	1.4	180	7.0	141	2.9	279	0.4	255	3.4
1,500	-----	-----	276	3.4	296	2.5	300	4.5	-----	-----	270	3.7	292	4.9	296	4.6	296	1.8	167	5.0	160	2.0	156	1.0	261	3.8
2,000	314	2.3	281	3.1	307	2.5	293	6.0	262	4.4	276	4.7	288	6.6	289	6.5	300	3.1	159	3.9	195	1.6	194	1.4	265	4.7
2,500	281	3.4	281	3.6	286	3.0	288	7.6	267	6.6	277	4.8	290	7.1	286	7.4	306	4.2	154	3.0	200	1.5	224	3.7	271	5.6
3,000	261	4.6	282	3.1	264	3.9	293	8.9	270	7.4	289	6.7	294	6.9	292	7.6	336	4.9	176	1.7	247	2.0	221	3.8	279	4.5
4,000	249	5.4	275	4.2	261	6.8	294	7.6	272	7.6	-----	-----	290	9.3	279	8.6	300	3.1	57	2.3	248	2.8	270	3.3	-----	-----
5,000	232	7.1	-----	-----	273	5.5	-----	-----	286	7.0	-----	-----	-----	-----	288	12.4	-----	-----	-----	-----	-----	-----	291	4.3	-----	-----

Altitude (meters m. s. l.	Newark, N. J. (14 m)		Oakland, Calif. (8 m)		Oklahoma City, Okla. (402 m)		Omaha, Nebr. (306 m)		Pearl Harbor, Territory of Hawaii[1] (68 m)		Pensacola, Fla.[1] (24 m)		St. Louis, Mo. (170 m)		Salt Lake City, Utah (1,294 m)		San Diego, Calif. (15 m)		Sault Ste. Marie, Mich. (198 m)		Seattle, Wash. (14 m)		Spokane, Wash. (603 m)		Washington, D. C. (10 m)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°		°	
Surface	32	0.8	259	1.7	160	2.4	93	0.7	55	4.0	327	0.7	228	0.9	142	3.0	48	1.5	322	0.5	177	1.0	87	1.6	263	0.5
500	334	2.3	259	3.4	176	5.1	151	1.9	67	6.6	228	2.7	225	4.2	-----	-----	335	2.1	301	1.7	223	1.7	-----	-----	278	4.2
1,000	304	2.8	290	3.4	207	8.9	231	3.1	78	7.5	225	3.2	254	5.6	-----	-----	324	2.4	292	3.6	234	1.8	170	1.0	293	3.6
1,500	288	5.0	305	2.5	216	6.3	261	5.6	81	7.8	210	2.4	268	7.3	153	3.9	305	4.8	297	3.8	221	1.1	230	1.8	291	4.1
2,000	285	6.5	278	1.3	235	3.8	266	5.9	88	5.6	223	1.2	269	8.1	180	2.5	-----	-----	319	4.9	217	2.1	233	2.2	287	5.3
2,500	297	7.8	244	1.2	256	3.0	280	6.6	88	5.0	171	0.3	280	6.7	209	1.9	-----	-----	318	5.9	217	3.0	245	3.0	287	6.8
3,000	289	8.0	235	3.8	275	2.0	300	8.8	84	4.8	273	2.2	256	5.5	235	2.8	-----	-----	315	6.2	236	1.4	263	4.5	284	8.5
4,000	309	9.4	-----	-----	44	2.7	314	9.3	-----	-----	283	3.8	310	4.3	240	6.0	-----	-----	-----	-----	266	4.9	336	2.3	299	7.0
5,000	301	12.1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	250	9.8	-----	-----	-----	-----	-----	-----	7	5.6	312	6.4

[1] Navy stations.

TABLE 5.—*Maximum free-air wind velocities, (M. P. S.), for different sections of the United States based on pilot-balloon observations during June 1937*

Section	Surface to 2,500 meters (m. s. l.)					Between 2,500 and 5,000 meters (m. s. l.)					Above 5,000 meters (m. s. l.)				
	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station	Maximum velocity	Direction	Altitude (m) M. S. L.	Date	Station
Northeast [1]	45.5	SW	1,000	14	Pittsburgh	39.2	W	4,130	14	Columbus	43.2	NNE	9,000	24	Albany.
East-Central [2]	28.4	W	2,190	10	Knoxville	28.0	W	3,059	10	Murfreesboro	40.0	NW	10,080	8	Greensboro.
Southeast [3]	26.3	NW	1,960	28	Spartanburg	26.7	NNW	3,640	22	Atlanta	34.4	NNW	5,740	22	Spartanburg.
North-Central [4]	27.9	SSE	1,688	17	Bismarck	31.2	NNW	3,070	21	Fargo	40.8	W	10,010	15	Detroit.
Central [5]	47.3	WSW	2,200	5	Omaha	46.8	WSW	2,560	5	Omaha	34.0	SW	6,822	7	Indianapolis.
South-Central [6]	33.8	SW	1,530	9	Abilene	35.0	WSW	4,270	5	Amarillo	38.0	NW	9,960	7	Dallas.
Northwest [7]	30.8	NNE	670	7	Pendleton	35.4	SSW	4,293	21	Spokane	34.6	N	7,733	4	Spokane.
West-Central [8]	34.8	SSW	633	16	Redding	42.6	SSW	3,735	16	Modena	47.7	WNW	6,975	4	Modena.
Southwest [9]	35.8	WSW	1,704	9	Winslow	40.6	WSW	3,018	4	Winslow	37.4	WSW	5,960	9	Albuquerque.

[1] Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and northern Ohio.
[2] Delaware, Maryland, Virginia, West Virginia, Southern Ohio, Kentucky, Eastern Tennessee, and North Carolina.
[3] South Carolina, Georgia, Florida and Alabama.
[4] Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota.
[5] Indiana, Illinois, Iowa, Nebraska, Kansas, and Missouri.
[6] Mississippi, Arkansas, Louisiana, Oklahoma, Texas (except El Paso), and western Tennessee.
[7] Montana, Idaho, Washington, and Oregon.
[8] Wyoming, Colorado, Utah, northern Nevada, and Northern California.
[9] Southern California, southern Nevada, Arizona, New Mexico, and extreme west Texas.

RIVERS AND FLOODS

[River and Flood Division, MERRILL BERNARD in charge]

By BENNETT SWENSON

The precipitation during June was normal or considerably above normal over most sections of the country while limited areas received only scanty amounts. The principal areas of above-normal precipitation were from Oklahoma northeastward to lower Michigan and New York, the Middle Atlantic Coastal Plains, New Mexico, northeastern Colorado, Washington, and in portions of Wyoming, Idaho, Oregon, and northern California. In portions of Washington the amounts were more than four times normal.

The floods resulting from excessive precipitation during the month are discussed below with a table of gage heights appearing at the end of the text.

Great Lakes drainage.—Floods in this section occurred from June 21 to 30 in the Red Cedar and Grand Rivers in Michigan, the St. Joseph River in Ohio and Indiana, and the Sandusky River in Ohio. These floods were the result of ample rains during the entire month with excessive rains occurring in the form of thunderstorms on the 20–21st and again on the 25th. The losses due to the floods were not extensive, except along the Sandusky River in Ohio, where damages amounting to $690,000 were reported, mostly to growing crops.

Atlantic slope drainage.—Minor floods occurred during the month in the Santee and Savannah Rivers in South Carolina. No damage was reported.

Upper Mississippi Basin.—Heavy local rains over northern Illinois on June 20–21 resulted in local floods in the Rock River from June 22–29. The flat character of the country permitted the overflow to spread out and the losses suffered were mainly damage to crops. Approximately 3,500 acres of growing crops were inundated with a loss of $200,000.

Minor flooding occurred in the Bourbeuse and Meramec Rivers in Missouri on June 10–12, but no losses of consequence were reported.

Missouri Basin.—Several local floods occurred in Montana during June but the most disastrous occurred at Billings, Mont., on the night of June 11–12. Among other localities flooded were Roundup, Klein, and Hinsdale, Mont. It is believed to be the first flood experienced at Billings in the 54 years of its history. The damage that occurred in the city and the immediate vicinity is conservatively estimated to be over $750,000.

Less severe floods in the Missouri Basin occurred in the upper Solomon River at Beloit, Kans., and in the lower Osage River in Missouri. The damage from the Solomon River was estimated at $12,000, most of which was to growing crops, and the Osage River, $45,500.

The greater portion of the Missouri River has been unusually low for a number of years as the result of deficient precipitation over much of the watershed. Sand bars and islands in the river that have not been inundated in the last few years are being used by farmers to an increasing extent to pasture cattle and some good crops have been produced of late on the bars that would, in most years, be flooded. For that reason, moderately high stages in the river after several years of low stages are of more than ordinary interest.

The unusually heavy rains from June 5–14 over Montana, Wyoming, North Dakota, and northern South Dakota resulted in a pronounced rise in the upper and middle Missouri River. Although the river exceeded flood stage only at Nebraska City, Nebr., it was necessary to issue warnings that the highest stage for several years during June would be reached from Bismarck, N. Dak., to St. Joseph, Mo., in order to protect livestock interests.

The high stages in the Missouri River resulted in damages amounting to about $285,000, mostly to growing crops. Heavy local rains on June 17 in the southern Black Hills region (Cheyenne River watershed) of South Dakota caused damages amounting to about $140,000 in the vicinity of Hot Springs, S. Dak.

Ohio Basin.—Floods in the Muskingum and Scioto Rivers in Ohio were caused by exceptionally heavy thunderstorms on June 21, together with abundant precipitation throughout the month, which left the ground in a saturated condition. The losses in the Muskingum River amounted to $712,000 and in the Scioto River, $100,000. The principal damage in each case was to growing crops.

Excessive rains occurred between 4 and 6 p. m. of the 21st over Gilmer and Lewis Counties in West Virginia and

parts of five adjoining counties. Glenville, W. Va., recorded 3.75 inches within a 2½-hour period. As a result of this storm the Little Kanawha rose rapidly, the stage at Glenville rising from 3.4 feet at 6 p. m. of the 21st, passing the flood stage of 23 feet at 10:30 p. m., and reaching a crest of 27.8 feet at 8 a. m. of the 22d. This flood was the third highest of record at Glenville and was very destructive in that vicinity, with losses estimated at $20,000.

Minor flooding occurred on the West Fork of the White River at Anderson, Ind., but no damage resulted.

Arkansas Basin.—During the first half of the month heavy rains fell over much of the Arkansas Basin. These rains resulted in light to moderate floods in the Cimarron, Neosho, and North and South Canadian Rivers and a general rise in the Arkansas River.

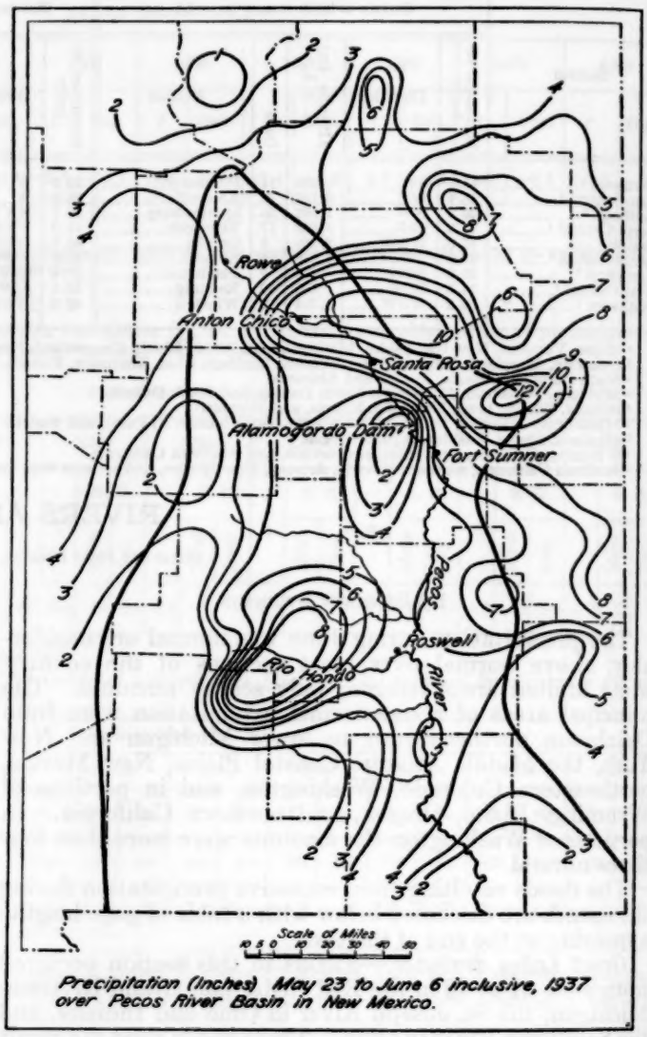
The Cimarron River reached a stage of 12.1 feet at Perkins, Okla. (flood stage 11 feet) on the 16th as the result of a heavy rain on the 9th followed by additional heavy rains on the 14th and 15th. About 1,200 acres of wheat were damaged with a loss estimated at $15,000.

There were two moderate overflows in the lower Neosho River, one on June 10–11 and the other on June 15–17. The first overflow reached a stage of 20.5 feet at Oswego, Kans., on the 10th (flood stage 17 feet) and the second overflow resulted in a stage of 22.6 feet on the 16th. The total loss was estimated at $66,000.

Excessive rains over the upper reaches of the Canadian River watershed at the close of May followed by frequent, heavy rains over much of the watershed during the first half of June resulted in a series of overflows along the North and South Canadian Rivers from May 31–June 26. The total losses incurred are estimated as follows: North Canadian in Oklahoma, $330,600; South Canadian in Oklahoma, $818,800; and North and South Canadian in New Mexico, $6,800.

West Gulf of Mexico drainage.—Exceptionally heavy and general rains occurred over much of eastern New Mexico beginning on May 23 and continuing at frequent intervals until June 6. The total precipitation during this period, particularly over the Pecos drainage is shown in the accompanying chart. A total amount slightly in excess of 12 inches (see table) was recorded at Ragland, N. Mex., and much greater amounts probably occurred at some points where no rain gages were located.

Another center of heavy precipitation was located a short distance north of Santa Rosa where more than 10 inches were recorded. However, an airplane pilot reported on the afternoon of June 1 that extremely heavy rain was falling over the upper Pecos River between Rowe and Anton Chico of which no actual measurement is available.



Precipitation (inches) May 23 to June 6 inclusive, 1937 over Pecos River Basin in New Mexico.

Daily precipitation, May 23–June 6, inclusive, 1937, at a few selected stations in the Pecos River drainage in New Mexico

Station	May									June						Total
	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	
Alamogordo Dam	0.14	0.14	.....	.....	.....	0.54	0.57	.....	.....	.....	.....	.....	.....	.....	.....	1.39
Artesia	.90	1.00	.....	.....	.....	3.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.04
Boaz	2.20	.93	.....	.....	.....	.....	.....	.....	3.75	.....	0.43	0.28	.....	.....	.....	7.59
Capitan	.....	.88	0.18	.....	0.31	2.16	.87	.....	.....	.17	.....	.....	.....	.....	.....	4.57
Corona	.01	1.31	.....	.....	.25	.18	1.68	.....	.....	.....	.....	.....	.....	.....	.....	3.43
Cuervo	.....	.78	.25	0.35	1.70	3.11	1.23	.....	.....	1.22	.....	.83	.....	.....	0.15	9.62
Doretta	.25	.75	.60	1.47	.23	.40	.42	0.04	.....	.....	.15	.10	0.08	.....	.....	4.49
Fort Sumner	.47	.15	.....	.34	.35	3.05	1.26	.18	.....	.....	.30	.28	.32	.....	.....	6.70
Palma	.....	.50	.25	1.20	.10	.50	.80	.....	.....	.02	.25	.03	.....	.....	.....	3.65
Ragland	.34	1.03	.....	1.78	2.02	2.45	1.45	.....	.28	.28	.65	1.76	.....	0.09	.....	12.13
Roswell	1.38	.66	.....	.....	.....	1.21	.29	.....	.19	.....	.....	.86	.....	.....	.05	4.04
Santa Fe	.44	.38	.....	.....	.27	.99	1.86	.....	.....	.36	.....	.....	.....	.....	.....	4.30
Santa Rosa	.....	.83	.....	.....	.50	2.10	2.20	.07	.....	.....	.50	.80	.15	.....	.15	7.30
Vaughn	.....	.94	.....	.40	1.10	.....	1.60	.50	.....	.....	.....	.50	.....	.....	.....	5.04
White Tail	1.20	1.57	.57	2.03	1.80	.33	.....	.56	.....	.67	.20	.....	.....	.....	.....	8.93

A third area of excessive precipitation was centered over the upper Rio Hondo. This rainfall resulted in the Rio Hondo overflowing its banks and flooding the city of Roswell on May 28–29. The losses suffered in Roswell are estimated at $13,500.

The excessive rainfall over the upper Pecos watershed gave rise to a serious situation along the Pecos River. The following report by the official in charge at Albuquerque, N. Mex., in regard to the floods in the Pecos River and in the Rio Grande is presented herewith:

Exceptionally heavy and general rains over eastern New Mexico caused much flood damage during May and June.

The most serious conditions were in the Pecos River watershed where record-breaking stages occurred. Extreme excessive rainfall occurred over a rather small area between Rowe and Anton Chico. This rainfall along with general rains over the entire watershed caused a peak stage at Santa Rosa of 29.0 feet, which is believed to be an all-time record.

The most serious problem was the unfinished Alamogordo Dam above Fort Sumner. The dam was nearly full of water from the May 28th rains and every effort possible was required to keep the dirt fill ahead of the water. This office received word of the excessive storm near Rowe from an airplane pilot and issued the warning to the officials at the Dam. Over 8 hours time was saved by issuing the warning when information was received from the pilot, instead of waiting until the water reached the gage at Santa Rosa.

Arrangements were made to warn the people in the Pecos Valley below Fort Sumner in case it was necessary to do so. Radio equipment was obtained and placed in planes ready to be sent to Fort Sumner in case telegraph and telephone lines failed. The Coast Guard was contacted at El Paso and they furnished much help by flying up and down the river and reporting flood conditions. They also stood by for possible help in case it would be necessary to issue flood warnings to the people below Fort Sumner.

Due to exceptionally heavy snowfall in the upper watershed of the Rio Grande the river was near flood stage at Espanola and Albuquerque, N. Mex., from May 1 to 31. No damage occurred at Espanola or Albuquerque, but some damage was reported at Bernalillo, about 20 miles north of Albuquerque, and much damage between Albuquerque and Elephant Butte Dam. The greatest damage occurred between Los Lunas and San Marcial. Much farming land in that section is lower than the normal river bed and is protected by dikes. The main flow of the river shifted, and this along with the continued high water caused many of the dikes to break on May 18, flooding rich farm lands and roads, and washing out tracks, etc.

On May 28 several severe thunderstorms occurred north and west of Socorro, about 3 p. m., causing a severe flood in the Rio Puerco and Rio Salado. Much damage occurred between Socorro and San Marcial, as the added water coming into the Rio Grande caused more dikes to break and added much water to already flooded areas. Much property and probably some lives were saved by advance warnings from this office, based on reports from two pilots that were in the vicinity of the severe rains when they occurred and reported direct by radio to this office. Some 2 hours' advance notice was given, which would have been impossible if the pilots had not reported, as there are no telephones or telegraph stations in that section. Four people in an automobile were trapped in an arroyo and were drowned.

The general rains during the first few days in June caused added trouble in the Rio Grande below Albuquerque, from the 1st to the 6th. Irrigation projects were flooded. The town of Belen was under water, and the low land between Socorro and San Marcial was again flooded. Road and railroad bridges were washed out below Socorro, blocking traffic between El Paso and Albuquerque.

Exceptionally heavy losses resulted from the overflows in the Pecos and Rio Grande in New Mexico during May and June, the greatest item being the damage to growing crops. The total estimated losses are as follows: Pecos River, $987,600; and Rio Grande, $787,500. The warnings are believed to have resulted in preventing a much greater loss.

Minor flooding occurred in the Guadalupe River in Texas from June 5–9, but no damage of consequence resulted.

Colorado Basin.—No floods occurred in the Colorado Basin except that an irrigation reservoir dam on the Gunnison River just above Austin, Colo., burst on June 13, resulting in severe local damage to the town of Austin and to approximately 3,000 acres of land. The estimated losses amounted to about $211,000.

Pacific Slope drainage.—The overflow in the San Joaquin Basin continued during the first part of June with stages in the Kings River exceeding flood stage at Piedra, Calif., from June 4–7. That portion of the water which could not be diverted for irrigation purposes continued to flow into Tulare Lake Basin until cooler weather during the latter half of the month brought about a more gradual run-off.

Although the precipitation was considerably above normal over the Columbia Basin during June flood stage was exceeded at only two points, Jefferson, Oreg., on the Santiam River and Vancouver, Wash., on the Columbia River. No damage resulted.

Corrections to April Report

Page 164, Table of flood stages.

Oneonta, N. Y., dates above flood stage and crest published as "From April 6, to April 7, crest 13.0 on April 6, 7" should be as follows (all dates in April):

Above flood stage—dates		Crest	
From—	To—	Stage	Date
6	9	14.0	6, 7
16	18	12.9	16
23	24	12.4	23

Table of flood stages during June 1937

[All dates in June unless otherwise specified]

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ST. LAWRENCE DRAINAGE					
Lake Michigan					
Red Cedar:	*Feet*			*Feet*	
Williamston, Mich.	7	25	27	7.1	26
East Lansing, Mich.	8	26	26	8.1	26
Grand:					
Eaton Rapids, Mich.	5	25	30	7.1	27
Lansing, Mich.	11	26	27	11.7	27
Lake Erie					
St. Joseph:					
Montpelier, Ohio	10	21	29	(1)	22
Fort Wayne, Ind.	12	25	27	13.2	26
Sandusky: Tiffin, Ohio	7	22	24	9.4	22
		25	27	9.6	26
ATLANTIC SLOPE DRAINAGE					
Santee:					
Rimini, S. C.	12	3	6	12.3	4
		22	27	12.5	25
Ferguson, S. C.	12	26	27	12.0	26, 27
Savannah: Ellenton, S. C.	14	22	22	14.2	22
MISSISSIPPI SYSTEM					
Upper Mississippi Basin					
Rock: Moline, Ill.	10	22	29	11.2	25
Bourbeuse: Union, Mo.	12	10	12	15.4	12
Meramec: Valley Park, Mo.	14	10	12	15.0	10
Missouri Basin					
Solomon: Beloit, Kans.	18	4	7	20.9	6
		16	16	18.0	16
Osage: St. Thomas, Mo.	23	10	14	27.2	12
Missouri: Nebraska City, Nebr.	15	21	[2] 29	16.5	25, 26
Ohio Basin					
Tuscarawas: Coshocton, Ohio	11	22	25	14.2	23
Muskingum:					
Lock No. 10, Zanesville, Ohio	25	22	23	27.6	22
Lock No. 7, McConnelsville, Ohio	22	22	24	26.6	22
Lock No. 3, Lowell, Ohio	25	22	23	25.2	23

[1] "Over gage"; gage graduated to 14 feet.
[2] Fell 0.3 foot below flood stage on 28th.

Table of flood stages during June 1937—Continued

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
Ohio Basin—Continued	Feet			Feet	
Little Kanawha: Glenville, W. Va.	23	21	22	27.8	
Scioto:					22
LaRue, Ohio	11	21	23	13.9	
Prospect, Ohio	10	22	25	11.5	22
Circleville, Ohio	14	22	25	19.3	23
		27	27	14.8	23
Chillicothe, Ohio	16	24	25	17.2	27
West Fork of White: Anderson, Ind.	8	4	6	8.3	24
		9	21	9.8	5
White Basin					15
Black: Black Rock, Ark.	14	11	12	14.6	
					11
Arkansas Basin					
Cimarron: Perkins, Okla.	11	16	16	12.1	16
Neosho: Oswego, Kans.	17	10	11	20.5	10
		15	17	22.6	16
North Canadian:					
		4	4	5.8	4
Woodward, Okla.	5	9	11	6.8	11
		13	13	5.4	13
		15	16	7.0	16
		4	4	6.0	4
Canton, Okla.	6	10	12	7.5	11
		15	18	8.2	17
Yukon, Okla.	8	May 31	9	10.0	6
		10	26	11.7	19
(East) Oklahoma City, Okla.	14	16	16	15.0	16

Table of flood stages during June 1937—Continued

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
Arkansas Basin—Continued					
Canadian:	Feet			Feet	
Canadian, Tex.	5	3	5	8.0	3
Union City, Okla.	7	3	4	7.8	4
		6	6	7.3	6
		9	10	9.2	10
Calvin, Okla.	15	1	1	15.0	1
Lower Mississippi Basin					
Big Lake Outlet: Manila, Ark.	10	12	26	12.6	17, 18
WEST GULF OF MEXICO DRAINAGE					
Guadalupe:					
Gonzales, Tex.	20	5	7	28.2	6
Victoria, Tex.	21	8	9	22.3	9
Pecos: Santa Rosa, N. Mex.	10	2	3	29.0	2
Rio Grande:					
Espanola, N. Mex.	7	(3)	6	(4)	
Albuquerque, N. Mex.	4	26	27	5.1	26
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Santiam: Jefferson, Oreg.	10	21	21	10.1	21
Columbia: Vancouver, Wash.	15	21	28	16.8	24

[3] Continued from previous month. [4] Crest occurred during previous month.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

(The Marine Division, I. R. TANNEHILL in charge)

NORTH ATLANTIC OCEAN, JUNE 1937

By H. C. HUNTER

Atmospheric pressure.—Over waters in the vicinity of western Europe and the British Isles pressure averaged above normal, Valencia, Ireland, showing a departure of +0.1 inch. The station at Belle Isle, Newfoundland, averaged 0.09 inch above normal, while the Gulf of Mexico had approximately normal pressure.

Most of the North Atlantic, however, averaged moderately below normal in pressure. The portions of the month notable for particularly low pressure were different as to area. The Greenland-Iceland area had low readings for the most part during the first fortnight and again during the final week; the Azores area from the 10th to 26th inclusive; and the Bermuda area, to an extent rather marked for the latitude and the season, from the 22d to the end of the month.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, June 1937*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
Julianehaab, Greenland	29.77	−0.09	30.26	17	29.26	2
Reykjavik, Iceland	29.83	−.05	30.42	16	29.18	26
Lerwick, Shetland Isles	29.88	+.09	30.27	12	29.29	28
Valencia, Ireland	30.10	+.10	30.48	15	29.62	6
Lisbon, Portugal	30.12	+.09	30.30	27	29.83	10
Madeira	30.11	+.04	30.30	26	29.97	10
Horta, Azores	30.15	−.09	30.48	8	29.78	11
Belle Isle, Newfoundland	29.95	+.09	30.36	18	29.56	13
Halifax, Nova Scotia	29.94	−.03	30.40	17	29.50	22
Nantucket	29.90	−.08	30.34	17	29.44	22
Hatteras	29.96	−.05	30.21	17	29.59	28
Bermuda	30.08	−.05	30.26	17, 18	29.78	29
Turks Island	30.02	−.01	30.07	5	29.91	25
Key West	29.99	.00	30.14	11	29.80	29
New Orleans	29.98	.00	30.20	11	29.71	29

NOTE.—All data based on a. m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

The extremes of pressure thus far reported are 30.64 and 29.03 inches. The higher mark was recorded on the American steamship *City of Havre*, late on the 17th, near latitude 48° N., longitude 26° W. The lower mark was noted on the Norwegian steamship *Sangstad*, at 8 a. m. of the 25th in about 67° N. 3° W., or approximately 350 miles to eastward of the northeastern limits of Iceland, from which locality very few vessel weather reports are received, even in Summer.

Cyclones and gales.—Scanning the series of monthly tables of ocean gales and storms, which this publication has presented since the latter part of 1924, brings to notice no other month with as few North Atlantic gales (force 8 or more) as June 1937. Three vessels encountered strong gales (force 9) and another a fresh gale (force 8), making four gales in all.

On the 4th and 5th two vessels reported strong gales about 700 miles west of Scotland. Both vessels were west-bound and their pressure readings were comparatively low for June.

During the night of the 14–15th two vessels noted respectively force 9 and force 8 when they were not far to eastward of the coast of New Jersey.

The table includes three instances of force 6 winds that were experienced in the south-central portion of the Caribbean Sea.

Fog.—June is expected to be a foggy month for much of the North Atlantic and during this June there was more fog than the average amount from the coasts of the North Atlantic States and the Maritime Provinces eastward to the Grand Banks and a short distance beyond; also a considerable number of reports of fog have come from squares north of 50° and near or somewhat to eastward of midocean. An area northwest of the Azores and another immediately to westward of Ireland and France reported less fog than is expected, but an area just northeast of the Azores reported more than the normal occurrence. In general fog occurred widely over the eastern North Atlantic about the 12th to 15th and during the final 4 days of the month.

The 5°-square adjacent to Maine, western Nova Scotia, and Cape Cod, namely 40° to 45° N., 65° to 70° W., led all other North Atlantic squares, with 23 days of fog. The period just preceding the middle of the month was the period with least fog in this area.

Fog was noted on about half the days of the month off the coast of New Jersey, but to southward reports were few, and south of the latitude of Hatteras there was practically no fog. Between the 15th and 65th meridians, south of 40° north latitude, no fog has been reported.

Several accidents due to fog have come to our notice, but there was apparently no loss of life connected with any. On the night of the 5–6th a barge sank after a collision in Long Island Sound. On or about the 24th a steamer grounded near Halifax, N. S., but soon was refloated. The last day of June saw three fog accidents in New England waters; also it was probably this day that the Norwegian steamship *Aranda*, bound into the Gulf of St. Lawrence, grounded off one of the Magdalen Islands and is expected to be a total loss.

OCEAN GALES AND STORMS, JUNE 1937

Vessel	Voyage		Position at time of lowest barometer		Gale began June—	Time of lowest barometer June—	Gale ended June—	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Georgian, Am. S. S.	New York	Cristobal	12 12 N.	78 35 W.	1	5p, 1	1	29.83	SE.	SE, 6	SE.	SE, 6	
Toloa, Am. S. S.	Santa Marta	Kingston	11 36 N.	74 18 W.	3	7a, 3	3	29.81	ENE.	ENE, 6	E.	E, 6	None.
Kentucky, Dan. S. S.	Oslo	Portland, Me.	56 52 N.	26 20 W.	4	2p, 4	6	29.22	SW.	W, —	NW.	W, 9	SW-W.
Hannah, Du. S. S.	Bremen	Montreal	58 22 N.	23 43 W.	4	10a, 5	5	[1] 29.17	SE.	SSW, 8	SSW.	S, 9	S-N.
Standard, Am. S.S.	Aruba	New York	39 42 N.	73 36 W.	14	7p, 14	14	29.76	WSW.	WSW, 9	W.	WSW, 9	SW-W.
Marinao, Ital. S. S.	Djidjelli	Gloucester, N. J.	38 10 N.	72 40 W.	14	—, 15	15	29.88	SSW.	SW, 8	SW.	SW, 8	SSW-W-SW.
Toloa, Am. S. S.	Kingston	Colon	13 25 N.	78 30 W.	17	3p, 18	18	29.80	E.	E, 6	ENE.	E, 6	
NORTH PACIFIC OCEAN													
Empress of Asia, Br. S. S.	Victoria, B. C.	Yokohama	51 25 N.	143 57 W.	[2] 31	4p, [2] 31	1	29.38	S.	S, 8	SW.	SW, 9	S-SSW.
Pres. Grant, Am. S. S.	Yokohama	Victoria, B. C	[3] 38 28 N.	146 47 E.	1	Mdt, 1	3	29.27	ENE.	N, 9	W.	NW, 10	NE-NW.
Tai Ping, Nor. M. S.	do	San Francisco	38 30 N.	150 00 E.	1	2a, 2	3	29.10	E.	SSW, 9	WNW.	W, 10	S-W.
Pres. Jefferson, Am. S. S.	Victoria, B. C	Yokohama	42 10 N.	149 45 E.	2	5a, 2	2	29.20	E.	NNE, 10	NW.	NNE, 10	NE-N.
San Diego Maru, Jap. M. S.	Osaka	San Francisco	39 41 N.	150 29 E.	1	6a, 2	3	29.00	E.	W, 7	WNW.	W, 8	S-W.
San Pedro Maru, Jap. M. S.	Yokohama	Los Angeles	40 40 N.	156 30 E.	1	Noon, 2	3	29.29	SE.	SW, 7	W.	SSE, 9	S-WSW.
Thames Maru, Jap. S. S.	Port Alice	Kobe	44 48 N.	156 58 E.	2	10p, 2	3	29.86	E.	NE, 8	NW.	NW, 9	E-N-NW.
Silverpalm, Br. M. S.	Cebu	San Francisco	42 50 N.	177 12 W.	2	6a, 3	2	29.44	S.	SW, 5	SW.	S, 8	
Nako Maru, Jap. M. S.	Yokohama	Los Angeles	[3] 43 21 N.	166 22 E.	2	Noon, 3	4	29.16	ESE.	SW, 9	WNW.	SW, 9	SW-WSW.
Salawati, Du. M. S.	Manila	do	39 16 N.	175 24 E.	3	3p, 3	4	29.78	S.	SSW, 7	WNW.	SSW, 9	SSW-WSW.
Empress of Asia, Br. S. S.	Victoria	Yokohama	[3] 50 45 N.	179 02 W.	3	9p, 3	3	29.33	S.	NE, 5	ESE.	ESE, 8	ESE-NE.
Tai Ping, Nor. M. S.	Yokohama	San Francisco	43 10 N.	179 00 E.	5	2p, 6	6	29.42	ESE.	WNW, 9	NW.	NNW, 9	ESE-WNW-NNW
San Pedro Maru, Jap. M. S.	do	Los Angeles	[3] 41 33 N.	152 03 W.	10	—, 10	10	29.49	SW.	S, 9	S.	S, 9	S-W.
Scottsburg, Am. S. S.	Manila	do	45 46 N.	178 05 W.	14	Noon, 14	17	29.10	W.	W, 9	W.	W, 9	
Shoyo Maru, Jap. M. S.	Kudamatsu	do	40 30 N.	137 30 W.	15	10a, 15	15	29.33	WSW.	W, 9	NW.	WNW, 9	W-WNW.
Chattanooga City, Am. S. S.	Hilo	Balboa	17 05 N.	117 50 W.	16	4p, 16	16	29.74	NNE.	SSE, 7	SSE.	W, 8	WNW-S-SE.
Scottsburg, Am. S. S.	Manila	Los Angeles	42 21 N.	140 00 W.	21	Noon, 21	22	29.58	SW.	SW, 8	W.	SW, 8	
Nitro, U. S. N.	San Diego	Balboa	18 00 N.	104 00 W.	25	11a, 25	25	29.63	E.	E, 10	SE.	E, 10	ENE-SSE.
Iowan, Am. S. S.	Balboa	Los Angeles	[3] 18 36 N.	104 42 W.	25	6a, 25	25	29.64	E.	ENE, 9	WNW.	ENE, 9	SE-ENE.
Silverbelle, Br. M. S.	Cebu	do	17 55 N.	130 28 E.	30	4p, 30	[4] 1	29.54	NW.	NE, 12	E.	NE, 12	NW-NE-SE.

[1] Barometer uncorrected.
[2] May.
[3] Position approximate.
[4] July.

NORTH PACIFIC OCEAN, JUNE 1937

By WILLIS E. HURD

Atmospheric pressure.—The Aleutian LOW continued in an abnormally high state of development for the month during June 1937, as in the previous May, with average center over eastern Aleutian waters, the mean pressure at Dutch Harbor being 29.73, which is 0.17 inch below the normal. The lowest barometer readings of the month were 28.90 inches, at Kodiak, on the 1st, and 28.88, read on the British steamer *Talthybius*, near 51° N., 174° W., on the 15th.

High pressure was central in the vicinity of Midway Island, where the average barometer, 30.14 inches, was 0.09 above the normal.

In the Far East, the encroachment of the continental LOW on the sea area is shown by the average barometer, 29.65 inches, at Hong Kong, and the average of 29.72 inches at Naha, in the Nansei Islands, both readings being below the normal.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, June 1937, at selected stations*

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	29.80	−0.19	30.12	9	29.50	7
Dutch Harbor	29.73	−.17	30.36	27	29.18	15,16
St. Paul	29.79	−.07	30.32	27	29.34	17
Kodiak	29.81	−.10	30.40	3	28.90	1
Juneau	29.94	−.07	30.58	3	29.35	18
Tatoosh Island	29.99	−.03	30.34	24	29.59	16
San Francisco	29.96	.00	30.19	11	29.74	27
Mazatlan	29.87	+.04	29.96	12	29.74	25
Honolulu	30.05	+.01	30.13	12	29.95	2
Midway Island	30.14	+.09	30.28	27	29.94	24
Guam	29.84	−.03	29.92	11	29.77	28
Manila	29.76	+.01	29.83	10, 14, 28	29.65	22
Hong Kong	29.65	−.05	29.76	10	29.50	17
Naha	29.72	−.03	29.83	1, 2, 10	29.53	18, 19
Chichishima	29.80	−.11	30.00	4	29.53	29
Nemuro	29.95	.....	30.18	29	29.77	26

NOTE.—Data based on 1 daily observation only, except those for Juneau, Tatoosh Island, San Francisco and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Extratropical cyclones and gales.—Although several traveling cyclones, as well as fluctuating depressions peculiar to the Aleutian LOW, appeared over upper waters of the North Pacific Ocean in June 1937, there were no storms of great intensity in the extratropics. Gales in this region in no instance exceeded 10 in force, and were largely reported as occurring during the first decade. The few gales of the middle and last decades were scattered as to time and locality and of force no higher than 9.

The severest storm affecting the weather of the upper steamship routes was that which came from the south of Japan on the 1st, and moved northeastward toward the Aleutians, then southeastward and eastward toward British Columbia, the coast of which it entered on the 9th. From the 1st to 3d a rather wide area of storminess lay east of northern and central Japan, several ships reporting gales of force 10, principally on the 2d, between 35°–45° N., 145°–155° E. Farther eastward, almost to midocean, gales of force 8–9 occurred on the 3d to 5th. No later gales were reported in connection with this cyclone, and no further gales were reported in upper east longitudes during the remainder of the month.

In connection with the cyclone in which the *Talthybius* reported the lowest barometer of the month, as previously noted, on the 15th, the American steamer *Scottsburg* encountered rough weather from the 14th to 17th, with a maximum wind-force of 9 on the 14th, near 46° N., 178° W.

On the eastern part of the ocean, roughly within the area 40°–52° N., 135°–152° W., gales of force 8–9 were reported on only four dates, the 1st, 10th, 15th, and 21st.

Tropical cyclones.—In the Far East one typhoon appeared at the end of the month between the Marianas and the Philippines. The British motorship *Silverbelle*, near 18° N., 130½° E., encountered a hurricane wind on the afternoon of the 30th, lowest barometer 29.54 inches. The storm moved westward and was over northern Luzon on July 2. There is no information yet available as to its intensity after the 30th, but it will receive further notice in the July issue of the REVIEW.

In the southeastern North Pacific a tropical cyclone showed signs of developing at some distance south of Acapulco on the 23d. On the morning of the 24th there was a LOW central near 13° N., 102° W., moving northward toward the Mexican coast. At 6 a. m. of the 25th the American steamer *Iowan* had an east-northeast gale of force 9, lowest barometer 29.64, a little south of Manzanillo, and at 10 a. m. the U. S. S. *Nitro* had an east gale of force 10, barometer 29.63, in 18° N., 104° W. Thereafter the storm appears to have moved northwestward and to have dissipated on the 26th near the mouth of the Gulf of California.

There were evidences of the formation of a tropical cyclone southwest of the Revillagigedo Islands on the 16th. The American steamship *Chattanooga City* reported a west gale of force 8 near 17° N., 118° W., barometer 29.74. The wind shifts observed on the vessel between noon and 4 p. m. were from north-northeast changing to west-northwest, west, south, and southeast. The disturbance was moving westward.

Fog.—Foggy weather was frequent, as is usual in June, particularly along the western part of the northern routes where, a day or two to the eastward of northern Japan, ships reported fog on nearly half the days of the month. South of the Aleutians fog was not reported, but it was observed in higher west longitudes, east of 160° W., on 7 days. In middle latitudes for the strip between 31° and 36° N., longitudes 180° and 155° E., there were 14 days with fog. In American coastal waters fog occurred on 7 days off Lower California, and on 3 or 4 days only along the coast of the United States.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, June 1937*

[For description of tables and charts, see REVIEW, January, p. 29]

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	80.2	+1.9	5 stations	103	[1] 25	Valley Head	51	23	3.66	−0.54	Robertsdale	7.83	Belgreen	0.34
Arizona	75.6	−1.2	Buckeye	118	30	McNary	26	3	.47	+.13	Santa Marguerita	2.40	6 stations	.00
Arkansas	78.8	+1.6	Hot Springs	106	27	Dutton	45	7	4.94	+.90	Corning	9.55	Little Rock	1.65
California	67.5	−.6	2 stations	120	21	Ellery Lake	13	1	.62	+.28	Crescent City (near)	8.03	74 stations	.00
Colorado	61.7	+.1	Las Animas	111	24	2 stations	15	[1] 5	1.93	+.52	Sedgwick	5.27	Paonia	T
Florida	80.4	+.6	2 stations	100	[1] 7	Plant City	57	1	5.71	−.95	Cottage Hill	12.86	Cedar Keys	.45
Georgia	79.8	+1.6	do	101	[1] 1	Blairsville	47	23	4.30	−.09	Abbeville	9.02	Newnan	.64
Idaho	59.5	−.8	Hollister	106	21	Pelton Ranch	17	5	1.68	+.38	Deception Creek	6.02	Glenns Ferry	T
Illinois	71.7	+.1	2 stations	102	[1] 24	Sycamore	37	11	5.07	+1.00	Freeport	8.65	Rock Island	2.06
Indiana	71.0	−.5	do	100	[1] 24	La Porte	39	11	4.56	+.78	Howe	10.19	Williams	1.43
Iowa	69.0	−.6	Oakland	108	24	2 stations	36	9	3.80	−.81	Hampton	7.49	Greenfield	1.09
Kansas	74.3	+.5	5 stations	109	[1] 23	do	38	5	3.27	−.71	Parsons	9.93	Richfield	.63
Kentucky	74.3	+.4	Bowling Green	99	25	do	46	12	4.52	+.39	Shepherdsville	7.09	Vanceburg	2.51

[1] Other dates also.

TABLE 1.—*Condensed climatological summary of temperature and precipitation by sections, June 1937*—Continued

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Louisiana	80.9	+.8	Plain Dealing	103	27	Franklinton	59	2	5.39	+.82	Paradis	16.75	Tallulah	1.95
Maryland-Delaware	72.3	+1.5	Cumberland, Md.	96	1	2 stations	41	[1] 13	4.99	+.95	Millsboro, Del.	10.33	Laurel, Md.	2.32
Michigan	63.6	−.4	Sidnaw	98	24	Vanderbilt	24	10	3.21	+.14	Jackson	11.69	Iron Mountain	.26
Minnesota	63.9	−1.0	Springfield	104	23	2 stations	29	9	3.21	−.81	New Ulm	7.98	2 stations	.99
Mississippi	80.4	+1.5	Moorhead	104	[1] 25	Utica	59	[1] 5	4.48	+.34	Swan Lake	10.38	Port Gibson	.96
Missouri	74.4	+.8	Oregon	105	25	Arcadia	43	7	4.93	+.31	Doniphan	10.46	Bethany	1.55
Montana	60.6	+.7	Scobey	108	30	Birch Creek Camp	16	6	2.59	+.11	Babb (near)	6.73	Wesby	.29
Nebraska	68.7	−.6	North Loup	113	23	Lodgepole	25	2	3.29	−.35	Cairo	8.45	Hyannis	.88
Nevada	65.7	+1.2	Logandale	114	21	Sheldon	24	12	.22	−.27	Hylton	1.57	9 stations	.00
New England	64.8	+.8	Orono, Maine	98	1	2 stations	34	16	4.59	+1.17	Salisbury, Conn.	9.75	Provincetown, Mass.	2.44
New Jersey	70.5	+1.7	Belvidere	99	1	3 stations	41	[1] 12	4.66	+.95	Newton	7.20	Belleplain	2.86
New Mexico	68.4	−.5	2 stations	106	[1] 20	2 stations	22	[1] 4	2.05	+.80	Isidore	8.58	3 stations	.00
New York	65.0	+1.1	do	98	1	Indian Lake	34	[1] 11	5.24	+1.55	Walden	8.41	Lowville	2.30
North Carolina	76.0	+2.0	do	100	[1] 2	Mount Mitchell	36	30	4.21	−.46	Monroe	10.30	Edenton	1.52
North Dakota	63.5	+.5	Wishek	109	23	Amindon	25	7	4.03	+.63	McClusky	9.34	Howard	.33
Ohio	69.7	+.2	Gallipolis (near)	98	1	3 stations	41	[1] 11	6.07	+2.29	Bucyrus	14.81	Chilo	2.71
Oklahoma	78.6	+1.3	Hollis	108	26	Boise City	42	5	3.72	−.07	Hugo	8.01	Cheyenne	.52
Oregon	60.0	+.4	Echo	106	28	Austin	13	5	3.30	+2.04	Brookings	14.08	Owyhee Dam	.32
Pennsylvania	69.5	+1.4	Ephrata	99	1	Somerset	38	[1] 12	4.37	+.27	Shippensburg	9.32	Huntingdon	1.59
South Carolina	79.1	+1.6	Clemson College	101	27	Long Creek (near)	50	23	4.78	+.07	Beaufort (near)	9.67	Effingham	1.30
South Dakota	65.3	−1.1	Wagner	112	23	2 stations	29	[1] 5	3.66	+.28	McIntosh	7.25	Tyndall	1.57
Tennessee	76.5	+1.7	Savannah	101	25	Crossville	47	12	3.70	−.48	Carthage	7.72	Coldwater	.85
Texas	81.3	+1.1	Henrietta	110	26	3 stations	40	[1] 4	2.67	−.29	Orange	7.30	Raymondville	.00
Utah	63.4	−1.2	Leeds (near)	115	20	Silver Lake	19	5	.38	−.19	Loa	2.00	6 stations	T
Virginia	73.6	+1.9	2 stations	98	1	Mountain Lake	40	12	4.92	+.78	Orange	9.48	Staunton	2.01
Washington	60.6	+.7	3 stations	104	28	3 stations	29	4	4.38	+2.79	Snoqualmie Pass	16.67	Pleasant View	.92
West Virginia	70.8	+1.2	Martinsburg	101	1	Bayard	40	[1] 9	5.03	+.69	Pickens	10.13	White Sulphur Springs	1.25
Wisconsin	64.4	−.7	Meadow Valley	101	26	Big St. Germain Dam.	26	9	2.82	−1.17	Beloit	6.62	Ashland (near)	.55
Wyoming	57.7	−1.0	4 stations	103	[1] 22	Foxpark	16	5	2.41	+.79	Kirtley (near)	7.11	Sage	.35
Alaska (May)	39.7	−1.8	Wrangell	73	8	Barrow	−6	8	1.69	−.15	Cordova	12.60	McKinley Park	.00
Hawaii	73.8	+.5	Mana Pump	93	[1] 26	Kanaloholuhulu	42	11	4.01	−.84	Keauhou #2	34.20	12 stations	.00
Puerto Rico	78.7	+.5	Arecibo	96	[1] 26	Lares	57	12	3.58	−1.50	La Mina (El Yunque)	11.86	2 stations	.24

[1] Other dates also.

TABLE 2.—*Climatological data for Weather Bureau stations, June 1937*

[Compiled by ANNIE E. SMALL, by official authority, U. S. Weather Bureau]

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation			Wind						Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01 inch or more	Average hourly velocity	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							64.4	+1.0										79	4.20	+1.2										6.5		
Eastport	76	67	85	29.84	29.92	−0.01	57.0	+1.9	81	1	66	44	3	49	32	54	52	86	3.23	+.3	16	8.0	sw.	30	e.	4	2	11	17	7.3	0.0	0.0
Greenville, Maine	1,070	6	40																												
Portland, Maine	103	82	117	29.79	29.91	−.04	63.8	+1.3	95	1	70	53	4	57	27	58	53	74	3.95	+.7	17	7.7	s.	19	sw.	9	13	8	9	5.3	.0	.0
Concord	289	60		29.61	29.91	−.05	65.6	+2.7	93	1	76	48	16	55	33				3.48	+.3	7		ne.				7	10	13		.0	.0
Burlington	403	11	48	29.46	29.89	−.07	64.4	−1.3	86	1	74	46	16	55	32	59	55	72	3.97	+.6	12	7.3	s.	25	s.	3	3	14	13	6.6	.0	.0
Northfield	876	12	60	28.98	29.91	−.05	61.1	−.2	87	1	73	40	16	49	36	58	54	76	3.81	+.6	11	6.4	s.	21	nw.	12	3	15	12	6.9	.0	.0
Boston [1]	29	31	50	29.87	29.90	−.06	66.4	−.1	95	1	74	53	3	59	28	60	56	76	3.47	+.6	13	8.6	e.	26	sw.	10	5	9	16	6.9	.0	.0
Nantucket	12	14	90	29.89	29.90	−.08	61.8	+.8	77	13	68	50	3	56	20	59	58	93	4.74	+2.1	15	11.9	n.	32	s.	14	5	6	19	7.1	.0	.0
Block Island	26	11	46	29.88	29.91	−.06	63.4	+1.6	77	15	69	54	3	58	18	61	60	92	3.82	+1.2	14	11.3	sw.	29	sw.	1	3	10	17	7.0	.0	.0
Providence	160	215	251	29.74	29.91	−.06	67.8	−.5	93	1	77	53	3	58	28	61	57	73	3.14	+.5	16	9.1	nw.	29	sw.	10	7	8	15	6.2	.0	.0
Hartford	159	66	100	29.74	29.91	−.06	68.8	+1.7	95	1	78	52	17	59	30				8.08	+5.0	17	6.9	s.	30	nw.	1	10	7	13	5.6	.0	.0
New Haven	106	74	153	29.80	29.91	−.06	68.7	+2.1	89	1	77	54	17	61	25	62	57	71	4.54	+1.4	14	7.5	n.	21	s.	10	7	9	14	6.5	.0	.0
Middle Atlantic States							72.2	+1.9										69	4.76	+1.1										6.2		
Albany	97	97	112	29.80	29.90	−.07	68.8	+.8	93	1	78	54	10	59	30	61	57	68	5.31	+1.9	12	6.9	s.	24	n.	10	6	11	13	6.1	.0	.0
Binghamton	871	57	79	28.97	29.92	−.05	67.8	+2.2	93	1	79	49	23	57	33				5.55	+2.2	14	5.3	ne.	21	ne.	21	2	12	16	7.3	.0	.0
New York	314	415	454	29.57	29.90	−.08	70.6	+1.8	89	1	78	54	11	63	23	63	59	71	3.07	−.3	15	11.2	n.	51	nw.	10	4	12	14	6.6	.0	.0
Harrisburg	374	94	104	29.51	29.90	−.09	72.2	+1.9	94	1	81	56	11	63	27	64	59	69	7.14	+3.6	10	6.5	w.	32	w.	14	6	19	5	5.6	.0	.0
Philadelphia	114	174	367	29.80	29.92	−.06	72.6	+1.2	91	6	81	55	11	64	24	65	61	69	3.51	+.3	11	11.5	sw.	31	sw.	14	5	14	11	6.3	.0	.0
Reading	323	283	306	29.56	29.90		72.0	+2.2	93	1	81	54	12	63	25	64	60	71	3.10	−.4	15	9.7	se.	45	nw.	14	6	14	10	6.3	.0	.0
Scranton	805	72	104	29.07	29.92	−.06	69.2	+1.4	93	1	80	51	12	59	31	62	57	69	5.89	+2.2	12	6.0	n.	24	nw.	10	6	15	9	5.7	.0	.0
Atlantic City	52	37	172	29.86	29.91	−.07	69.5	+2.9	87	7	76	54	12	64	23	65	62	82	3.45	+.4	15	14.3	s.	36	ne.	11	2	13	15	7.2	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, June 1937*—Continued

[Compiled by ANNIE E. SMALL, by official authority, U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Middle Atlantic States—Continued	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Sandy Hook	22	10	57	29.88	29.90	.....	70.0	+2.2	90	1	77	58	11	63	22	64	62	78	3.86	+0.1	12	10.7	e.	43	se.	14	6	9	15	6.2	0.0	0.0
Trenton	190	88	106	29.71	29.90	.....	71.2	+1.7	92	6	81	54	11	62	28	64	60	71	4.05	+1.0	12	8.5	n.	25	s.	10	7	11	12	6.2	.0	.0
Baltimore	123	100	215	29.78	29.91	−0.08	75.2	+2.5	93	1	84	60	11	66	26	66	62	69	3.53	−.4	11	9.9	sw.	43	nw.	14	6	13	11	6.1	.0	.0
Washington	112	62	85	29.79	29.91	−.09	75.1	+2.9	92	1	85	56	12	66	27	67	64	73	5.23	+1.1	16	6.3	sw.	33	nw.	14	7	14	9	5.8	.0	.0
Cape Henry	18	8	54	29.91	29.93	.....	75.1	+2.2	94	14	83	56	13	67	25	69	67	80	3.67	−.3	12	9.7	sw.	35	nw.	30	6	17	7	5.5	.0	.0
Lynchburg	686	148	184	29.22	29.95	−.06	75.9	+1.3	96	1	87	57	24	65	31	68	65	78	6.24	+2.4	16	6.4	sw.	37	nw.	10	3	22	5	5.5	.0	.0
Norfolk	91	80	125	29.84	29.94	−.06	76.8	+2.4	94	6	86	60	12	68	28	68	65	74	7.49	+3.3	11	8.5	sw.	37	nw.	7	5	12	13	6.4	.0	.0
Richmond	144	11	52	29.79	29.93	−.08	76.4	+2.3	93	2	86	56	12	66	27	68	65	75	6.02	+2.1	13	7.0	sw.	30	nw.	10	7	13	10	5.9	.0	.0
Wytheville	2,304	49	55	.....	29.97	−.04	69.8	+1.1	88	1	80	52	12	59	31	.....	.....	74	3.77	−.4	17	5.8	w.	21	w.	10	4	17	9	.....	.0	.0
South Atlantic States							78.8	+2.4										75	4.36	−0.3									5.6		
Asheville	2,253	89	104	27.68	29.96	−.05	72.6	+3.9	89	20	84	55	30	62	31	64	62	77	4.13	+.2	16	6.1	nw.	32	se.	5	4	20	6	5.9	.0	.0
Charlotte	779	63	86	29.14	29.96	−.05	78.2	+2.7	96	1	88	62	30	68	27	69	66	72	5.35	+1.1	12	6.2	sw.	30	s.	7	2	16	12	6.2	.0	.0
Greensboro [1]	886	6	56	29.02	29.96	.....	76.3	.....	95	1	87	60	24	65	31	68	65	76	3.59	.....	13	7.2	sw.	31	nw.	30	3	19	8	5.9	.0	.0
Hatteras	11	5	50	.....	29.96	−.05	76.7	+1.1	86	28	82	62	13	72	19	.....	.....	79	2.69	−1.8	6	11.9	sw.	34	nw.	5	11	14	5	.....	.0	.0
Raleigh	376	103	146	29.54	29.93	−.08	78.0	+2.3	96	1	89	60	12	67	31	69	66	73	3.81	−.6	10	8.0	sw.	36	nw.	30	9	19	2	4.9	.0	.0
Wilmington	72	73	107	29.90	29.96	−.05	78.2	+1.4	94	15	86	63	12	70	21	71	69	78	3.93	−1.2	9	9.0	sw.	31	s.	19	7	20	3	4.9	.0	.0
Charleston	48	11	92	29.93	29.98	−.03	80.8	+1.9	98	28	88	68	30	73	25	73	70	75	3.11	−1.5	8	9.5	sw.	28	n.	28	3	13	14	6.5	.0	.0
Columbia, S. C	347	70	91	29.60	29.97	−.04	79.8	+1.7	98	28	90	64	30	70	27	70	67	73	6.20	+2.0	13	7.7	s.	27	sw.	7	6	21	3	5.2	.0	.0
Greenville, S. C	1,039	139	.....	.....	.....	.....	78.9	+4.8	95	2	89	62	30	68	27	.....	.....	.....	2.86	−1.7	8	.....	sw.	.....	.....	.....	9	12	9	.....	.0	.0
Augusta	182	62	77	29.76	29.95	−.06	81.0	+2.3	98	28	91	67	30	71	27	71	68	72	3.32	−1.4	16	5.9	s.	24	nw.	11	3	22	5	5.8	.0	.0
Savannah	65	73	152	29.91	29.98	−.03	81.4	+2.4	96	28	91	68	11	72	26	73	70	78	7.83	+2.5	10	9.3	sw.	51	nw.	15	2	23	5	5.5	.0	.0
Jacksonville	43	86	110	29.95	30.00	−.01	81.5	+1.6	95	28	90	68	1	73	23	73	70	76	4.73	−.6	10	7.5	s.	28	sw.	29	4	22	4	5.5	.0	.0
Florida Peninsula							81.1	+0.8										77	5.11	−1.0									5.9		
Key West	22	10	64	29.97	29.99	.00	82.0	+.1	91	27	87	71	16	77	15	76	74	79	6.04	+1.8	13	8.9	se.	30	w.	24	7	10	13	6.0	.0	.0
Miami	25	124	168	29.98	30.01	+.01	81.2	+1.2	89	23	86	71	26	76	16	74	72	74	3.83	−3.0	14	8.8	se.	29	s.	30	5	15	10	6.4	.0	.0
Tampa	35	88	197	29.97	30.00	−.01	81.4	+1.2	93	6	89	67	1	73	21	73	71	77	5.91	−1.3	11	9.4	w.	35	n.	7	7	16	7	5.4	.0	.0
Titusville	43	5	36	29.94	29.99	.....	79.8	+.5	96	2	91	61	1	68	31	73	72	.....	4.67	−1.6	13	.....	sw.	.....	.....	.....	1	19	10	.....	.0	.0
East Gulf States							80.4	+1.8										73	4.62	0.0									5.8		
Atlanta [1]	976	5	53	28.96	29.95	−.06	79.6	+3.6	97	13	90	63	30	69	28	70	66	70	6.06	+2.3	12	7.0	w.	35	sw.	28	2	18	10	6.5	.0	.0
Macon	370	79	87	29.57	29.96	−.05	80.7	+1.8	97	1	91	64	30	71	27	71	67	69	1.81	−2.2	11	6.4	s.	24	n.	28	4	19	7	6.0	.0	.0
Thomasville	273	49	58	29.70	29.99	−.01	80.0	+.5	94	13	90	66	12	70	24	73	71	.....	6.02	+.6	15	.....	sw.	.....	.....	.....	.....	.....	.....	.....	.0	.0
Apalachicola	35	11	.....	29.95	29.99	.....	81.0	+1.2	92	27	88	69	6	74	19	74	72	75	3.83	−1.8	12	7.3	w.	26	se.	18	8	13	9	5.5	.0	.0
Pensacola	56	149	185	29.93	29.99	.00	79.6	+.3	92	23	85	67	18	74	19	74	71	78	8.98	+4.3	13	10.3	sw.	51	s.	5	6	21	3	4.8	.0	.0
Anniston	741	9	.....	.....	.....	.....	79.4	+4.4	98	25	91	60	23	68	32	.....	.....	.....	2.78	−1.3	11	.....	nw.	.....	.....	.....	10	15	5	.....	.0	.0
Birmingham	700	11	48	29.21	29.96	−.03	80.4	+2.5	100	25	91	63	8	70	28	70	66	69	1.77	−2.7	7	5.7	s.	21	se.	5	9	16	5	4.7	.0	.0
Mobile	57	86	161	29.92	29.98	−.01	80.6	+.3	95	22	89	68	6	72	24	73	71	76	7.21	+1.8	16	7.7	s.	38	se.	26	4	15	11	6.8	.0	.0
Montgomery	218	92	105	29.73	29.97	−.03	81.5	+1.9	99	25	91	68	7	72	25	72	68	72	2.53	−1.3	10	6.3	sw.	24	sw.	5	5	17	8	5.8	.0	.0
Meridian	375	67	92	29.58	29.96	−.02	80.3	+2.2	98	25	91	66	30	70	29	71	68	73	4.42	−.1	12	5.3	sw.	20	se.	1	7	12	11	6.0	.0	.0
Vicksburg	247	82	102	29.72	29.97	.00	80.6	+1.6	96	27	90	67	12	72	22	72	69	73	1.10	−2.9	9	6.7	sw.	25	nw.	28	7	15	8	5.5	.0	.0
New Orleans	53	76	84	29.92	29.98	.00	81.6	+1.0	95	22	89	66	15	74	20	73	71	74	8.87	+3.0	18	5.7	se.	19	nw.	28	5	14	11	6.2	.0	.0
Port Eads	9	4	35	.....	.....	.....	81.8	.....	93	23	89	68	7	75	20	.....	.....	.....	6.12	.....	12	7.8	s.	32	sw.	5	13	12	5	.....	.0	.0
West Gulf States							81.5	+1.8										72	3.29	−0.3									4.4		
Shreveport	249	92	227	29.68	29.94	−.02	82.4	+1.7	101	27	92	64	5	73	24	73	70	70	3.47	.0	8	9.2	s.	43	n.	28	12	13	5	4.5	.0	.0
Bentonville	1,303	12	38	28.55	29.88	−.06	76.2	+2.1	96	23	87	50	7	66	33	.....	.....	.....	7.21	+3.0	6	5.3	sw.	22	sw.	2	9	13	8	.....	.0	.0
Fort Smith	457	79	94	29.45	29.91	−.03	80.6	+3.1	100	27	90	60	7	71	26	71	66	67	3.32	−.4	9	6.6	e.	24	w.	17	11	13	6	4.6	.0	.0
Little Rock	357	94	102	29.57	29.94	−.02	79.7	+2.3	98	27	89	60	6	71	25	71	67	69	1.66	−2.1	11	7.1	s.	22	w.	10	10	9	11	5.2	.0	.0
Austin	605	68	90	29.29	29.92	.....	82.0	+.8	99	30	91	64	5	73	27	72	69	70	3.92	+1.5	7	7.9	s.	27	n.	6	17	10	3	3.9	.0	.0
Brownsville	57	88	96	29.83	29.89	.....	83.2	+.8	97	29	90	72	3	76	20	76	74	81	.12	−2.8	3	10.8	se.	28	se.	4	17	11	2	3.7	.0	.0
Corpus Christi	20	11	78	29.89	29.91	.00	83.1	+2.1	93	29	88	65	4	78	21	76	75	80	.82	−1.8	1	12.6	se.	37	n.	4	16	10	4	3.5	.0	.0
Dallas	512	220	227	29.38	29.91	.....	81.7	.....	100	27	91	57	6	73	23	71	66	65	4.65	+.7	8	10.0	s.	42	e.	4	14	10	6	4.1	.0	.0
Fort Worth	679	92	110	29.22	29.92	.00	81.8	+1.9	101	27	92	57	6	72	24	.....	.....	.....	5.74	+2.4	8	9.1	s.	36	n.	8	17	11	2	2.8	.0	.0
Galveston	54	106	114	29.90	29.96	+.01	82.9	+2.2	93	23	87	65	4	78	19	76	74	78	1.18	−3.2	5	10.8	s.	33	nw.	4	11	15	4	5.1	.0	.0
Houston	138	292	314	29.81	29.95	.....	82.6	+1.2	99	30	91	64	4	74	29	.....	.....	.....	3.12	−1.4	9	10.3	s.	27	s.	7	7	20	3	4.9	.0	.0
Palestine	510	64	72	29.42	29.94	.00	81.4	+2.4	98	27	91	62	5	72	28	72	68	69	2.76	−.9	5	6.8	s.	23	s.	4	10	16	4	4.7	.0	.0
Port Arthur	34	98	106	29.92	29.96	.....	81.8	.....	95	30	89	65	4	75	24	75	73	77	5.90	+1.1	10	9.6	s.	35	nw.	30	8	15	7	5.2	.0	.0
San Antonio	693	242	301	29.20	29.90	.00	82.5	+1.5	102	30	93	63	4	72	28	72	68	69	2.19	−.3	4	10.4	se.	30	ne.	6	10	17	3	4.7	.0	.0
Ohio Valley and Tennessee							74.2	+1.4										70	4.26	+0.3									6.1		
Chattanooga	762	71	214	29.16	29.95	−.05	79.5	+4.1	97	25	90	64	12	69	27	69	64	65	2.82	−1.3	10	6.6	w.	44	w.	16	7	18	5	5.5	.0	.0
Knoxville	995	66	84	28.92	29.95	−.05	77.2	+3.2	92	27	87	61	12	67	28	67	63	68	2.52	−1.6	15	5.4	ne.	20	sw.	4	5	22	3	5.1	.0	.0
Memphis	399	78	86	29.53	29.94	−.03	79.2	+1.6	96	27	87	65	12	71	22	71	67	69	4.07	+.5	10	6.7	sw.	40	sw.	10	9	10	11	5.7	.0	.0
Nashville	546	168	188	29.40	29.97	−.02	78.1	+2.5	96	25	88	59	12	68	29	68	63	66	2.65	−1.4	12	7.7	nw.	31	w.	16	5	18	7	5.5	.0	.0
Lexington	989	6	.....	.....	.....	.....	75.4	+3.2	95	1	88	50	12	62	33	.....	.....	.....	5.80	+1.8	13	.....	sw.	.....	.....	.....	12	13	5	.....	.0	.0
Louisville	525	188	234	29.39	29.97	−.01	75.1	+.4	92	1	84	55	12	67	25	67	63	70	4.14	+.3	8	8.9	n.	45	ne.	3	6	17	7	5.9	.0	.0
Evansville	431	76	116	29.49	29.95	−.02	76.6	+1.5	97	25	86	55	30	68	27	67	62	65	5.09	+1.0	11	7.7	n.	42	sw.	9	5	12	13	6.3	.0	.0
Indianapolis	822	194	230	29.08	29.95	−.02	71.4	−.2	89	20	80	50	11	62	26	63	58	67	3.69	+.1	10	9.7	n.	32	w.	7	1	18	11	6.6	.0	.0
Terre Haute	575	63	149	29.33	29.93	.....	73.6	.....	99	25	84	52	11	63	28	65	60	68	5.90	+2.0	14	8.6	n.	31	sw.	13	6	16	8	5.8	.0	.0
Cincinnati	627	11	51	29.29	29.96	−.03	72.7	+1.5	93	1	82	53	12	63	27	65	62	75	3.66	.0	11	6.1	n.	25	sw.	9	4	13	13	6.8	.0	.0
Columbus	822	90	210	29.09	29.94	−.05	71.6	+.7	90	26	80	52	11	63	25	64	60	69	6.71	+3.4	12	8.3	n.	42	sw.	14	6	13	11	6.1	.0	.0
Dayton	899	60	163	29.01	29.94	.....	71.6	+.2	90	1	80	52	11	63	25	.....	.....	.....	4.80	+1.0	13	7.3	n.	28	sw.	9	6	13	11	5.9	.0	.0
Elkins	1,947	59	78	27.97	29.96	−.04	67.6	+.7	86	5	78	47	24	57	36	62	59	79	4.11	−1.0	16	5.1	nw.	24	e.	1	2	16	12	7.1	.0	.0
Parkersburg	637	77	84	29.31	29.96	−.04	72.5	+1.1	92	1	82	52	12	62	30	65	62	76	5.35	+1.4	15	5.4	nw.	35	nw.	21	3	15	12	6.5	.0	.0
Pittsburgh [1]	1,273	39	54	28.61	29.94	−.05	70.2	−.5	91	1	80	52	11	61	28	62	58	69	2.65	−1.2	11	9.2	nw.	42	nw.	14	4	14	12	6.6	.0	.0

[1] Observations taken at airport.

TABLE 2.—*Climatological data for Weather Bureau stations, June 1937*—Continued

[Compiled by ANNIE E. SMALL, by official authority, U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. +2 mean min.	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								0–10	*In.*	*In.*
Lower Lake Region							66.9	+0.2										71	6.12	+2.8										6.1		
Buffalo	768	243	280	29.10	29.92	−0.05	65.2	+.8	88	25	71	51	10	59	24	60	57	74	5.94	+3.1	13	10.9	sw.	40	sw.	21	8	14	8	5.6	0.0	0.0
Canton	448	10	61	29.43	29.90	.....	64.7	−1.1	84	25	74	47	23	55	30	60	56	74	6.77	+3.5	15	6.7	w.	22	w.	9	5	15	10	6.2	.0	.0
Ithaca	836	77	100	29.03	29.91	.....	66.5	+.3	91	1	78	47	12	55	36	60	56	71	6.07	+2.5	16	6.5	nw.	25	se.	17	3	12	15	7.2	.0	.0
Oswego	335	71	85	29.55	29.91	−.06	64.9	+.1	82	20	72	50	11	58	24	60	56	73	3.22	.0	10	6.7	w.	25	n.	10	9	9	12	6.3	.0	.0
Rochester	523	86	102	29.37	29.93	−.04	66.8	+.7	86	25	75	50	11	58	28	59	54	66	3.76	+.8	14	7.0	sw.	29	sw.	7	10	9	11	5.5	.0	.0
Syracuse	596	65	79	29.28	29.91	−.06	67.2	+1.6	87	1	76	49	11	58	31	.....	.....	.....	6.59	+2.7	12	6.3	nw.	19	nw.	8	6	12	12	6.3	.0	.0
Erie	714	130	166	29.17	29.93	−.05	67.2	+1.0	85	25	74	52	10	60	24	61	57	72	6.64	+3.3	11	9.9	nw.	33	nw.	14	10	13	7	5.2	.0	.0
Cleveland	762	267	318	29.13	29.94	−.04	67.5	+.4	84	5	74	54	10	61	20	61	57	72	6.64	+3.5	14	11.5	nw.	38	sw.	20	8	11	11	5.7	.0	.0
Sandusky	629	5	67	29.28	29.95	−.03	69.2	+.4	88	5	77	53	12	61	25	.....	.....	.....	12.51	+9.0	15	7.6	sw.	21	nw.	14	6	13	11	6.2	.0	.0
Toledo	628	79	87	29.28	29.95	−.02	68.7	−.0	87	5	77	50	11	61	23	62	58	71	6.67	+3.3	15	8.6	w.	24	nw.	14	6	16	8	5.6	.0	.0
Fort Wayne	857	69	84	29.04	29.95	.....	68.2	−1.1	88	20	77	48	11	59	25	61	57	71	4.44	+.9	16	8.2	nw	31	sw.	20	6	12	12	6.4	.0	.0
Detroit [1]	626	5	78	29.27	29.94	−.03	67.1	−.3	87	26	76	46	11	58	28	60	56	68	4.14	+.6	17	8.5	nw.	40	sw.	20	3	13	14	6.7	.0	.0
Upper Lake Region							63.0	+0.6										69	3.13	−0.2										5.9		
Alpena	609	13	89	29.28	29.95	−.01	61.7	+1.3	82	6	70	42	10	53	26	56	51	71	2.55	−.8	8	9.8	nw.	30	nw.	25	8	10	12	5.7	.0	.0
Escanaba	612	41	49	29.29	29.95	+.01	61.8	+1.1	86	25	71	38	9	52	27	55	50	67	1.82	−1.4	7	7.7	s.	25	s.	6	6	17	7	5.6	.0	.0
Grand Rapids	707	70	244	29.19	29.95	−.02	67.4	−.4	92	24	76	48	30	58	27	59	55	68	4.68	+1.2	11	9.6	n.	43	sw.	6	9	9	12	5.5	.0	.0
Lansing	878	5	90	29.01	29.94	.....	64.7	−1.7	85	26	74	42	10	56	28	60	57	78	6.77	+3.3	12	7.4	s.	22	s.	25	5	11	14	6.7	.0	.0
Ludington	637	5	54	29.26	29.95	.....	61.6	+1.1	85	25	71	40	10	52	31	56	52	.....	4.24	+1.3	8	.....	n.	.....	.....	.....	15	6	9	.....	.0	.0
Marquette	734	44	69	29.13	29.93	−.01	61.4	+2.5	96	24	71	39	1	52	37	55	51	70	.66	−2.6	9	7.6	s.	29	s.	6	7	16	7	5.2	.0	.0
Sault Sainte Marie	614	11	52	29.27	29.96	.00	59.0	+.4	84	16	70	39	4	48	38	53	47	67	1.15	−1.8	4	7.2	w.	24	sw.	6	9	11	10	5.8	.0	.0
Chicago	673	7	131	29.24	29.96	.00	65.9	−1.4	97	24	73	48	11	58	27	59	55	72	5.02	+1.7	12	9.7	ne.	29	sw.	6	7	14	9	5.8	.0	.0
Green Bay	617	109	141	29.28	29.93	−.02	65.6	+.7	95	24	78	42	9	56	32	57	51	62	1.39	−2.3	11	9.8	s.	37	sw.	6	4	13	13	6.7	.0	.0
Milwaukee	681	97	221	29.22	29.95	.00	63.8	−.1	97	24	72	46	9	56	35	56	51	66	2.64	−.8	9	11.1	n.	36	sw.	6	8	9	13	6.1	.0	.0
Duluth	1,133	5	47	28.70	29.91	−.01	60.4	+3.2	81	27	71	38	8	50	35	54	49	72	3.51	−.4	7	10.0	ne.	30	w.	7	8	11	11	5.8	.0	.0
North Dakota							64.2	+1.1										62	3.01	−0.6										5.1		
Moorhead, Minn	940	50	58	28.90	29.91	+.01	63.6	−.8	87	23	74	37	7	53	33	57	51	67	1.89	−2.2	11	7.9	s.	25	w.	6	6	10	14	6.5	.0	.0
Bismarck	1,674	8	57	28.14	29.90	+.03	64.6	+.9	99	23	76	36	7	53	34	56	50	64	6.09	+2.7	9	9.9	se.	37	nw.	5	10	12	8	5.2	.0	.0
Devils Lake	1,478	11	44	28.36	29.91	+.03	62.7	+.8	98	23	74	33	8	51	34	55	50	67	3.50	−.1	8	9.5	s.	32	ne.	4	10	9	11	5.3	.0	.0
Grand Forks	833	12	67	.....	.....	.....	63.2	+.2	92	23	75	36	7	51	37	58	.....	.....	2.80	−.6	7	.....	nw.	29	se.	22	12	8	10	.....	.0	.0
Williston	1,878	42	50	27.94	29.89	+.03	66.9	+4.2	101	29	79	36	7	54	37	53	43	48	.78	−2.6	7	9.6	se.	30	nw.	23	16	11	3	3.4	.0	.0
Upper Mississippi Valley							70.7	+0.1										69	3.96	−0.2										5.9		
Mpls.—St. P., Minn.	919	105	208	28.96	29.93	+.01	67.2	−.3	99	23	76	43	8	58	30	58	52	61	3.11	−1.1	9	9.6	se.	30	se.	12	9	7	14	6.2	.0	.0
La Crosse	714	11	48	29.17	29.93	.00	67.4	−.9	95	24	77	39	9	58	29	60	56	72	3.81	−.3	10	4.9	nw.	21	sw.	6	8	10	12	5.8	.0	.0
Madison	974	70	78	28.91	29.93	−.01	66.4	−.8	94	24	74	44	9	58	25	59	55	69	3.15	−.6	12	7.3	n.	26	sw.	6	3	14	13	6.7	.0	.0
Charles City	1,015	10	51	28.88	29.93	+.02	66.8	+.3	96	23	77	39	9	56	30	61	56	71	4.36	−.3	12	5.9	se.	25	nw.	12	9	10	11	5.4	.0	.0
Davenport	606	66	161	29.29	29.94	.00	71.1	+.6	99	25	80	46	10	62	27	63	58	67	2.56	−1.6	9	9.5	ne.	32	sw.	13	7	13	10	5.8	.0	.0
Des Moines	861	5	99	29.04	29.93	+.01	70.8	+.2	100	23	81	47	9	61	30	63	58	68	3.95	−.8	9	9.0	n.	30	w.	13	4	16	10	6.0	.0	.0
Dubuque	699	60	79	29.20	29.94	+.01	68.8	−.6	97	24	78	46	10	60	26	61	56	68	5.98	+1.7	9	5.7	nw.	19	sw.	6	7	9	14	6.4	.0	.0
Keokuk	614	64	78	29.29	29.93	−.01	72.4	−.1	99	25	82	51	9	63	27	65	60	68	2.14	−2.0	9	6.9	sw.	26	n.	25	7	11	12	6.1	.0	.0
Cairo	358	87	93	29.56	29.94	−.03	77.4	+1.1	96	25	85	59	12	70	22	69	65	70	3.06	−.8	8	7.2	n.	28	sw.	3	4	8	18	6.9	.0	.0
Peoria	609	11	45	29.30	29.96	+.01	70.8	−.1	99	24	81	45	11	60	30	64	61	74	4.87	+1.1	8	6.1	ne.	20	n.	25	12	10	8	4.5	.0	.0
Springfield, Ill	636	5	191	29.27	29.94	−.01	73.4	+1.2	100	25	83	50	11	64	28	65	61	70	4.72	+.7	14	10.0	sw.	32	s.	13	5	15	10	6.0	.0	.0
St. Louis	568	179	303	29.34	29.94	−.01	75.4	+.4	98	25	84	55	10	67	24	66	62	67	5.84	+2.0	14	10.2	sw.	43	sw.	1	9	14	7	5.3	.0	.0
Missouri Valley							72.0	+1.1										67	3.87	−0.5										5.3		
Columbia, Mo	784	6	64	29.11	29.92	−.03	74.2	+1.4	99	25	84	52	10	65	26	.....	.....	.....	4.01	−.8	13	6.9	s.	24	ne.	13	12	8	10	5.3	.0	.0
Kansas City [1]	750	32	45	29.13	29.91	−.01	75.8	+2.2	100	24	85	52	10	67	26	67	62	69	3.73	−1.3	9	8.7	sw.	26	nw.	2	6	14	10	5.7	.0	.0
St. Joseph	967	11	49	28.91	29.92	.....	73.9	.....	103	24	84	50	9	64	28	65	61	69	1.64	−3.3	10	7.9	e.	27	w.	5	14	9	7	4.6	.0	.0
Springfield, Mo	1,324	98	104	28.57	29.94	−.01	74.9	+2.4	95	25	83	58	6	66	25	67	64	73	9.39	+4.7	10	8.0	s.	43	nw.	9	13	9	8	4.5	.0	.0
Topeka	987	65	87	28.87	29.90	.....	76.2	+2.8	105	25	87	51	10	65	34	66	61	66	1.14	−3.5	5	8.8	s.	24	sw.	12	10	13	7	5.1	.0	.0
Lincoln	1,189	11	81	28.66	29.90	.00	72.7	+1.3	106	23	84	46	10	62	38	63	57	64	3.79	−.5	12	9.6	se.	32	sw.	5	12	6	12	5.4	.0	.0
Omaha [1]	982	31	44	28.88	29.91	.00	72.2	+.6	104	23	83	46	10	62	31	63	58	68	4.77	+.2	9	10.3	se.	34	sw.	5	9	10	11	5.8	.0	.0
Valentine	2,598	47	54	27.27	29.95	+.09	66.4	−.5	107	23	77	39	7	55	43	56	49	62	1.40	−1.5	9	9.5	e.	32	nw.	5	8	12	10	5.5	.0	.0
Sioux City	1,138	64	106	28.71	29.90	.00	69.8	+.3	105	23	80	45	10	60	30	61	56	65	5.11	+1.1	12	9.2	se.	35	nw.	6	5	15	10	6.1	.0	.0
Huron	1,307	59	74	28.53	29.91	+.03	65.8	−.4	106	23	76	39	8	55	36	58	53	66	3.69	.0	10	9.1	se.	37	w.	6	13	8	9	4.8	.0	.0
Northern Slope							61.5	+0.4										58	2.45	+0.2										6.0		
Havre	2,507	11	67	27.33	29.93	+.08	64.7	+2.7	101	29	78	39	9	51	43	51	39	46	3.73	+.9	7	9.7	sw.	32	nw.	23	11	14	5	4.6	.0	.0
Helena	4,124	85	11	25.84	29.98	+.10	58.7	−.5	97	29	71	35	6	47	38	48	40	56	2.27	−.1	13	8.4	sw.	32	sw.	16	4	7	19	7.2	.0	.0
Missoula	3,263	80	91	.....	.....	.....	61.0	+1.0	100	29	74	36	4	48	40	.....	.....	.....	1.08	−.8	13	7.5	e.	31	nw.	3	4	10	16	6.9	T	.0
Kalispell	2,973	48	56	26.96	29.98	+.09	58.9	+1.2	92	29	70	35	5	47	39	50	42	61	2.25	+.2	13	6.3	w.	38	sw.	29	3	10	17	6.9	.0	.0
Miles City	2,371	48	55	27.43	29.94	+.09	67.0	+1.0	98	29	78	40	8	56	35	54	44	50	2.00	−.7	6	6.7	s.	26	n.	23	6	14	10	5.5	.0	.0
Rapid City	3,259	50	58	26.61	29.98	+.13	63.8	−.4	102	23	74	35	5	53	38	55	49	62	2.77	−.6	7	8.5	s.	38	nw.	5	15	7	8	4.7	.0	.0
Cheyenne [1]	6,144	5	39	24.00	29.92	+.08	59.6	−.8	93	22	73	29	4	47	38	49	42	62	1.28	−.3	10	11.1	s.	42	nw.	12	6	12	12	5.9	3.0	.0
Lander	5,372	60	68	24.67	29.94	+.09	59.7	−.8	95	29	73	32	3	46	43	49	40	56	3.68	+2.5	13	5.7	sw.	41	sw.	22	7	13	10	6.1	8.5	.0
Sheridan	3,790	10	47	26.10	29.96	.....	60.2	.....	94	22	73	33	3	47	40	51	46	65	2.43	+.4	14	5.9	nw.	23	nw.	17	6	10	14	6.1	1.5	.0
Yellowstone Park	6,241	12	46	23.94	30.04	+.18	53.4	.0	87	29	65	29	6	42	39	44	36	60	2.35	+.7	11	8.3	sw.	30	nw.	3	4	9	17	6.7	1.8	.0
North Platte	2,821	11	51	27.05	29.92	+.06	68.2	+.7	104	22	79	43	7	57	38	59	53	67	3.15	−.1	8	7.9	se.	28	nw.	5	9	10	11	5.6	.0	.0
Middle Slope							72.9	+1.0										58	2.83	−0.2										4.6		
Denver	5,292	106	113	24.76	29.92	+.08	64.7	−1.6	95	22	77	34	4	53	35	52	44	55	2.39	+1.0	9	7.9	s.	27	n.	1	11	11	8	5.3	T	.0
Pueblo	4,685	80	86	25.29	29.87	+.04	70.0	+1.0	99	21	84	38	6	56	41	54	42	47	.51	−.8	7	7.7	e.	25	ne.	13	12	12	6	4.7	.0	.0
Concordia	1,392	50	58	28.46	29.90	.00	74.2	+1.2	106	24	85	49	9	63	38	63	57	61	2.28	−2.1	10	8.6	s.	24	s.	12	15	6	9	4.8	.0	.0
Dodge City	2,509	10	86	27.37	29.91	+.04	73.4	+.9	103	21	85	48	5	62	32	61	54	59	3.15	−.2	10	12.1	s.	35	nw.	4	14	8	8	4.2	.0	.0
Wichita	1,358	85	93	28.50	29.90	−.01	76.4	+2.0	101	24	86	52	6	67	28	66	59	61	3.99	−.4	6	10.3	se.	27	se.	12	15	8	7	4.3	.0	.0
Oklahoma City	1,214	10	47	28.65	29.90	−.01	78.8	+2.8	100	26	89	60	6	69	25	68	63	66	4.65	+1.0	9	9.0	s.	26	sw.	2	13	10	7	4.6	.0	.0

[1] Observations taken at Airport.

TABLE 2.—*Climatological data for Weather Bureau stations, June 1937*—Continued

[Compiled by ANNIE E. SMALL, by official authority, U. S. Weather Bureau]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01 inch, or more	Wind: Average hourly velocity	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Southern Slope							**79.4**	**+1.5**										**56**	**1.75**	**−0.8**										**3.4**		
Abilene	1,738	10	52	28.12	29.88	0.00	81.4	+2.2	101	28	93	59	6	70	35	68	62	59	2.82	−.2	6	10.2	s.	27	s.	12	19	7	4	3.4	0.0	0.0
Amarillo	3,676	10	49	26.25	29.89	+.04	74.4	+1.6	97	24	86	46	5	63	29	62	55	58	2.83	.0	8	9.6	se.	35	se.	7	15	11	4	3.8	.0	.0
Del Rio	960	63	71	28.86	29.82	−.03	85.0	+1.6	102	30	95	69	4	75	30	71	65	58	.44	−2.1	2	11.3	se.	30	ne.	28	13	16	1	4.2	.0	.0
Roswell	3,566	75	85	26.32	29.84	+.04	77.0	+.7	98	12	91	50	5	63	38	60	49	47	.91	−.8	2	8.0	s.	25	s.	3	23	7	0	2.0	.0	.0
Southern Plateau							**74.4**	**+0.4**										**36**	**1.09**	**+0.7**										**2.6**		
El Paso	3,778	82	101	26.12	29.77	+.02	82.4	+2.8	103	18	96	61	10	69	36	58	38	27	1.05	+.5	5	8.5	e.	27	e.	26	21	8	1	2.3	.0	.0
Albuquerque [1]	4,972	5	39	25.04	29.82	.....	70.8	−1.8	99	20	87	46	4	55	42	53	39	43	1.91	+1.4	6	8.7	n.	42	nw.	3	16	11	3	3.6	.0	.0
Santa Fe	7,013	38	53	23.30	29.86	+.05	65.1	+.3	92	20	77	40	4	53	33	50	39	46	3.51	+2.4	7	6.3	e.	18	w.	26	13	10	7	4.6	.0	.0
Flagstaff	6,907	10	59	23.39	29.82	+.04	58.7	−.6	91	20	75	32	1	43	43	45	.....	43	1.07	+.7	8	8.9	sw.	25	sw.	8	7	18	5	.....	.0	.0
Phoenix	1,107	39	51	28.64	29.76	+.02	85.3	+.8	108	26	101	62	1	70	38	60	40	25	T	−.1	0	6.5	e.	25	ne.	26	21	8	1	2.0	.0	.0
Yuma	141	9	54	29.62	29.76	+.02	85.6	+.9	112	30	103	59	1	69	39	64	48	35	.09	+.1	2	5.3	w.	20	se.	27	28	2	0	.6	.0	.0
Independence	3,957	5	26	25.91	29.87	+.09	73.0	+.7	99	20	89	46	1	57	39	52	32	.....	T	−.1	0	.....	nw.	.....	.....	.....	27	1	2	.....	.0	.0
Middle Plateau							**65.6**	**+0.6**										**39**	**0.10**	**−0.4**										**4.1**		
Reno	4,527	61	76	25.46	29.92	+.06	63.8	+1.4	95	27	78	38	12	50	42	49	37	43	.03	−.3	2	7.7	w.	27	w.	21	17	11	2	3.7	.0	.0
Tonopah	6,090	12	20	.....	.....	.....	66.2	.....	90	20	79	41	12	54	30	49	34	36	T	.....	0	.....	nw.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Winnemucca	4,344	18	56	25.59	29.92	+.04	63.6	+.8	98	28	80	37	5	47	44	48	35	41	.14	−.6	5	8.2	ne.	26	nw.	22	14	8	8	4.3	.0	.0
Modena	5,473	10	43	24.60	29.83	+.01	63.8	+.5	95	21	81	36	1	47	44	47	31	36	.10	−.2	1	10.5	sw.	35	sw.	11	17	10	3	3.4	T	.0
Salt Lake City [1]	4,227	32	46	25.69	29.87	+.02	66.8	.....	100	21	82	35	5	52	41	51	39	44	.14	.....	2	9.3	se.	49	w.	8	12	9	9	4.9	.0	.0
Grand Junction	4,602	60	68	25.34	29.86	+.03	71.0	−.4	96	28	85	40	5	57	36	52	37	35	.14	−.3	6	7.4	se.	27	sw.	11	14	11	5	4.0	.0	.0
Northern Plateau							**64.1**	**+0.5**										**52**	**1.60**	**+0.5**										**5.3**		
Baker	3,471	48	53	26.45	30.00	+.05	58.8	+.2	95	28	73	34	11	45	43	49	40	56	.99	−.4	7	6.2	n.	26	sw.	16	10	5	15	5.9	.0	.0
Boise	2,739	79	87	27.14	29.96	+.05	66.0	+.7	97	28	79	43	11	53	36	52	42	49	.44	−.5	6	5.8	nw.	24	nw.	3	12	9	9	4.7	.0	.0
Pocatello	4,477	60	68	25.46	29.92	+.05	62.4	+.2	96	21	76	36	5	49	40	49	38	46	.37	−.7	6	8.7	se.	38	sw.	11	10	12	8	4.9	.0	.0
Spokane	1,929	101	110	27.95	29.97	+.03	63.3	+.5	95	29	74	43	24	52	38	53	44	57	3.13	+1.8	12	6.6	s.	30	sw.	30	8	11	11	5.8	.0	.0
Walla Walla	991	57	65	28.89	29.95	−.01	67.6	+1.1	101	28	79	49	4	56	36	55	45	51	1.91	+.8	10	5.2	s.	27	w.	22	13	6	11	5.1	.0	.0
Yakima	1,076	58	67	28.82	29.96	.....	66.6	+.2	98	28	78	46	17	55	36	54	44	52	2.73	+2.1	12	6.4	nw.	28	ne.	7	11	4	15	5.6	.0	.0
North Pacific Coast Region							**60.9**	**+2.6**										**74**	**3.55**	**+1.9**										**6.6**		
North Head	211	11	56	29.78	30.01	+.02	56.4	+1.6	84	5	61	48	1	52	33	54	52	89	3.13	+.8	11	15.0	nw.	59	se.	18	5	6	19	7.3	.0	.0
Seattle	125	90	321	29.85	29.98	−.02	63.0	+4.0	86	27	71	50	23	55	31	55	49	69	3.15	+1.8	14	8.7	n.	42	w.	22	10	10	10	5.6	.0	.0
Tatoosh Island	86	10	54	29.91	30.00	−.02	55.2	+2.2	68	5	60	47	3	51	16	52	50	85	5.40	+2.2	10	9.9	sw.	35	s.	17	4	5	21	7.5	.0	.0
Medford [1]	1,329	29	58	28.56	29.94	.....	65.2	.....	100	27	79	41	23	52	50	55	48	64	1.71	+1.0	13	.....	w.	.....	.....	.....	10	5	15	5.9	.0	.0
Portland, Oreg	153	68	106	29.82	29.97	−.07	65.4	+3.0	92	28	75	47	24	56	32	57	51	68	3.88	+2.4	15	6.8	nw.	19	ne.	5	9	4	17	6.4	.0	.0
Roseburg	510	45	76	29.43	29.98	−.05	64.6	+2.1	99	28	76	43	24	53	44	57	51	70	4.04	+3.0	14	4.6	n.	21	sw.	22	8	3	19	6.7	.0	.0
Middle Pacific Coast Region							**66.1**	**+1.8**										**64**	**1.25**	**+0.8**										**5.2**		
Eureka	62	73	89	29.95	30.02	−.03	58.0	+3.7	69	20	63	44	2	53	19	54	51	82	1.35	+.6	10	7.0	sw.	24	sw.	26	4	6	20	7.6	.0	.0
Redding [1]	722	20	34	.....	.....	.....	73.6	−1.5	106	27	84	49	17	63	32	58	46	44	2.87	+2.1	6	8.3	nw.	31	se.	16	11	6	13	5.3	.0	.0
Sacramento	66	92	115	29.85	29.92	+.03	71.4	+2.0	108	27	85	52	17	58	39	58	50	54	.18	.0	1	7.9	sw.	20	sw.	7	18	10	2	2.9	.0	.0
San Francisco	155	112	132	29.80	29.97	+.01	61.4	+2.9	87	26	68	48	2	55	29	56	52	78	.59	+.4	4	10.6	w.	26	w.	11	8	14	8	5.1	.0	.0
South Pacific Coast Region							**69.4**	**+0.7**										**65**	**0.00**	**−0.1**										**3.6**		
Fresno	327	97	105	29.55	29.90	+.05	75.6	−.2	109	27	90	55	12	61	36	60	48	44	T	−.1	0	8.0	nw.	26	nw.	21	19	7	4	2.9	.0	.0
Los Angeles	338	159	191	29.56	29.92	+.02	67.8	+1.4	92	30	76	55	7	60	26	60	56	72	.00	−.1	0	5.7	sw.	15	sw.	16	20	8	2	3.3	.0	.0
San Diego	87	62	70	29.83	29.92	.00	64.9	+1.0	84	30	70	57	12	60	22	60	57	79	.01	.0	1	6.9	w.	18	nw.	30	13	12	5	4.7	.0	.0
West Indies																																
San Juan, P. R	82	9	54	29.95	30.04	.....	80.4	+.7	90	27	85	72	10	76	15	.....	.....	.....	3.83	−1.5	13	12.8	e.	29	e.	2	2	25	3	4.9	.0	.0
Panama Canal																																
Balboa Heights	118	6	92	.....	[3] 29.83	+.01	80.2	+.1	91	3	86	72	8	74	16	.....	.....	[2] 86	7.44	−.8	17	4.9	nw.	21	s.	18	0	23	7	7.0	.0	.0
Cristobal	36	6	97	.....	[3] 29.85	+.02	81.2	+.8	90	27	86	72	10	76	14	76	75	[2] 84	26.91	+13.0	26	6.0	se.	24	sw.	10	1	7	22	8.3	.0	.0
Alaska																																
Fairbanks	454	11	87	[3] 29.24	[3] 29.74	.....	61.8	+3.7	91	11	75	40	6	49	41	52	44	60	.74	−.6	8	6.8	s.	28	se.	1	7	12	11	5.7	.0	.0
Juneau	80	96	116	[3] 29.85	[3] 29.94	.....	55.7	+1.4	83	10	64	43	2	48	35	49	44	70	4.76	+1.2	19	5.2	s.	29	se.	11	8	5	17	6.7	.0	.0
Nome	22	5	32	[3] 29.77	[3] 29.79	.....	46.8	+1.4	78	12	55	26	7	38	33	43	40	78	.56	−.8	5	7.0	w.	25	n.	1	6	12	12	6.2	.0	.0
Hawaiian Islands																																
Honolulu	38	86	100	[3] 30.01	[3] 30.05	.....	76.6	.0	84	22	80	68	6	73	12	69	65	70	.44	−.5	15	10.1	e.	25	e.	25	9	18	3	4.5	.0	.0

[1] Observations taken at airport.
[2] Observations taken bihourly.
[3] Pressure not reduced to a mean of 24 hours.

TABLE 3.—*Data furnished by the Canadian Meteorological Service, June 1937* [1]

Station	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
Cape Race, N. F.	99	29.92	30.03	+0.09	51.4	+3.8	58.8	43.9	76	35	8.82	+4.46	0.0
Sydney, C. B. I.	48	29.88	29.93	−.02	60.4	+5.0	70.0	50.9	88	40	2.12	−.73	.0
Halifax, N. S.	88	29.68	29.94	−.02	59.9	+2.1	67.0	52.8	78	46	7.38	+3.40	.0
Yarmouth, N. S.	65	29.82	29.92	−.04	59.8	+4.6	67.8	51.8	78	44	4.72	+1.78	.0
Charlottetown, P. E. I.	38	29.86	29.94	+.01	60.3	+2.9	68.3	52.3	82	42	4.91	+2.03	.0
Chatham, N. B.	28	29.80	29.91	.00	60.2	+.5	70.4	50.0	86	41	5.20	+1.68	.0
Father Point, Que.	20	29.84	29.86	−.02	55.0	+2.3	63.7	46.2	77	39	2.27	−.44	.0
Quebec, Que.	296	29.59	29.91	+.01	63.5	+2.2	72.0	54.9	81	47	4.76	+.76	.0
Doucet, Que.	1,236	28.58	29.92	+.01	56.6	+1.5	70.2	42.9	90	24	4.41	+.46	.0
Montreal, Que.	187												
Ottawa, Ont.	236	29.64	29.89	−.03	64.6	+.1	75.5	53.8	84	46	3.64	+.45	.0
Kingston, Ont.	285	29.60	29.92	−.02	64.0	+1.4	70.8	57.1	85	49	4.87	+1.97	.0
Toronto, Ont.	379	29.51	29.90	−.07	65.9	+2.5	74.5	57.3	84	48	3.64	+.84	.0
Cochrane, Ont.	930				58.1		69.3	46.8	88	34	4.15		.0
White River, Ont.	1,244	28.60	29.93	+.01	58.1	+.9	72.8	43.4	91	30	1.10	−1.38	.0
London, Ont.	808	29.09	29.96	−.01	63.6	−1.2	73.1	54.1	86	42	3.18	+.13	.0
Southampton, Ont.	656	29.24	29.94	−.01	60.1	−.2	70.3	49.9	83	38	3.93	+1.38	.0
Parry Sound, Ont.	688	29.24	29.92	−.04	63.3	+1.6	73.4	53.2	87	46	3.08	+.66	.0
Fort Arthur, Ont.	644	29.28	29.98	+.05	56.6	−.4	67.8	45.3	85	31	2.90	+.05	.0
Winnipeg, Man.	760	29.07	29.89	−.02	62.4	.0	75.0	49.9	90	36	2.32	−.76	.0
Minnedosa, Man.	1,690	28.11	29.90	+.01	59.3	−.3	72.5	46.0	91	30	4.07	+1.07	.0
Le Pas, Man.	860				61.2		72.8	49.6	90	33	.95		.0
Qu'Appelle, Sask.	2,115	27.64	29.89	+.02	62.8	+3.1	77.8	47.8	96	26	1.08	−2.41	.0
Moose Jaw, Sask.	1,759	27.95	29.90	+.07	65.4	+5.1	80.0	50.9	103	33	.30	−2.74	.0
Swift Current, Sask.	2,392	27.38	29.90	+.04	63.4	+3.2	78.4	48.4	100	34	.49	−2.47	.0
Medicine Hat, Alb.	2,365	27.46	29.91	+.05	64.2	+1.1	77.4	51.0	102	37	.70	−1.76	.0
Calgary, Alb.	3,540												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.36	29.89	+.01	63.0	+4.3	76.1	49.9	98	35	1.05	−1.72	.0
Battleford, Sask.	1,592	28.16	29.88	+.01	63.2	+4.8	79.8	46.7	101	28	.58	−2.30	.0
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262	28.64	29.97	+.05	66.4	+2.4	79.9	52.8	101	44	.68	−.62	.0
Victoria, B. C.	230	29.73	29.98	−.03	58.5	+2.2	65.9	51.0	82	48	2.21	+1.01	.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20	30.00	30.02	−.02	55.3	+2.3	60.6	50.0	73	44	4.75	+1.00	.0
Prince Rupert, B. C.	170	29.78	29.96	−.06	54.4	+1.4	63.4	45.5	79	40	4.01	−.02	.0
St. George's, Bermuda	158		30.07	−.05	76.2	+1.8	81.3	71.0	87	67	6.37	+1.44	.0

[1] Effective June 1937, monthly pressure, temperature, and precipitation departures based on new respective monthly normals, furnished by the Canadian Meteorological Service.

TABLE 4.—*Severe local storms, June 1937*

[Compiled by Mary O. Souder from reports submitted by Weather Bureau officials. The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list of tornadoes will appear in the United States Meteorological Yearbook]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Boone County, Iowa	1	2:45 p. m.	100	0	$4,000	Tornado	Property damaged.
Norton, Kans., vicinity of	1	7 p.m.	[1] 2		3,000	Heavy hail	Loss to crops; path 5 miles long.
Princeton, S. C.	1			0	3,000	Tornado	Buildings wrecked.
Gainesboro, Tenn.,[2] vicinity of	2	P. m.		2		Heavy rain	Cloudburst, worst in the history of this locality, swept 2 elderly women to their death and demolished their cabin. More than 100 livestock drowned; several barns washed away.
Woodruff, S. C.	2				600	Electrical	Barn and contents burned.
Roswell, N. Mex., vicinity of	3	Noon	[1] 1		4,000	Hail	Loss to crops; path 4 miles long.
McCamey, Tex.	3	7 p. m.	[1] 5		50,000	Wind	4 persons injured; path 10 miles long.
York County, Pa.	3	P. m.		1	15,000	Electrical	Barn and its contents destroyed. Farmer burned to death attempting to rescue livestock. Near Lewisberry barn burned with $10,000 loss.
Jefferson County, Ky.	3				25,000	Thundersquall	Trees, roofs, and electrical equipment damaged.
Smith County, Kans., southeast portion.	4	5:30–7 p. m.	[1] 3		45,000	Heavy hail	Chief loss to wheat; path 7 miles long.
Johnson City, Tenn.[2]	4				15,000	Thundersquall	Several buildings unroofed; telephone service disrupted; houses flooded, because of heavy rain and inadequate sewers.
Pulaski County, Ark.	5		880–1,320		3,500	Heavy hail and wind.	$3,000 loss to crop by hail; property damaged by wind $500.
Chicago, Long Lake, Ill., and vicinity.	5			2		Wind	Uprooted tree fell across 2 automobiles smashing the cars and injuring father and son. 2 boys drowned in Long Lake when their boat upset; several men rescued. Small private planes grounded at the municipal airport. Windows blown in.
Harmon County, Okla.	7	5:50–6:20 a. m.	[1] 5–8		1,250,000	Rain and hail	Rainfall measured from 5 to 8.5 inches. More than 3 inches of hail on the ground in low places. In gullies ice accumulated to a depth of several feet. Much damage to fruit and orchards. 12,000 acres of ripe wheat, 60,000 acres of cotton plants, and 40,000 acres of grain sorghum total loss, estimated at $750,000; property damage $500,000; path 25 miles long.
Beckham County, Okla., southwest portion.	7	7:30 a. m.	[1] 12		150,000	Hail	Damage principally to crops; path 25 miles long.
Norfolk, Va., vicinity of	7	7:50 p. m.			3,500	Thundersquall and hail.	Electric service delayed, automobiles stalled, and windows broken. Hail damaged growing crops.
Perry County, Ky.	7				25,000	Rain	Damage to railway and highway bridges; bottom-lands flooded.
Aiken County, S. C.	7				4,000	Thunderstorm	Barns and outbuildings unroofed.
Shamrock, Tex., vicinity of	7		[1] 1–5		70,000	Hail	No details.
Stratford, Tex.	7				100,000	do	School building damaged.

See footnotes at end of table.

TABLE 4.—*Severe local storms, June 1937*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Pampa, Tex.	8	4 a. m.	[1] 30		$275,000	Hail	Crop loss $100,000; property damage $175,000.
Arnett, Okla., and vicinity	8	5 a. m.	[1] 1–3		35,000	do	Principal loss to crops; total loss over some areas; path 8 miles long.
Greer County, Okla.	8	5:30–7:30 a. m.	[1] 5		275,000	do	Crop loss $250,000; property damage $25,000; path 30 miles long.
Perrin, Tex.	8	4 p. m.	[1] 5	0	105,500	Tornado	Crop loss $80,000; property damage $25,000; farm stock $500.
Weatherford, Tex., vicinity of	8	4:25 p. m.	[1] 8		250,000	Hail and wind	Loss to crops; buildings damaged; stock killed.
Johnson County, Kans.	8	5 p. m.	100	0	15,000	Tornado	Church and parsonage demolished and 2 persons injured near Big Bow. Path 880 yards long, not well-defined.
Partridge to Sterling, Kans., vicinity of.	8	7 p. m.	[1] 3		250,000	Heavy hail and wind	Chief loss to wheat; path 25 miles long.
Stevens County, Kans.	8	7:30 p. m.	880	1	45,000	Tornado	All buildings on a farm, 5 miles east of Moscow, totally demolished. Many other farm buildings in storm's path damaged; path 8 miles long.
Howard, Kans., vicinity of	8	11 p. m.	[1] 2		5,000	Heavy hail	Loss to crops; path 3 miles long.
Harper County, Kans.	8–9	Midnight	[1] 7		50,000	Heavy hail and wind	Chief loss to wheat; path 25 miles long.
Burlington, Cherokee, and Helena, Okla., and vicinities.	9	1–3 a. m.	[1] 1–3		350,000	Hail	Storm covered 3 distinct areas. Crop loss $175,000; property damage $175,000; path from 4 to 10 miles long.
Springfield, Mo.	9	3:30 a. m.			50,000	Tornadic wind and rain.	Damage to public utilities. 5,000 homes in darkness. 1,000 trees either uprooted or badly damaged.
Decatur, Ark., and vicinity	9	4 a. m.	440	0	37,000	Tornado	More than 100 houses damaged in Decatur; $2,000 loss in orchards.
Greeley, Colo.	9	4:30 p. m.	400	0		do	Storm struck on the campus of the State College of Education. Trees uprooted or broken; telephone and power lines, and automobiles damaged; path 880 yards long.
Union City to Moore, Okla., and vicinities.	9	4:30–6 p. m	200–440	1	55,000	Tornado, heavy rain, and hail.	A well-defined, pendant, funnel-shaped cloud with rotary motion was observed at all points affected. 7 persons injured. Heavy hail was experienced from 4:30 to 5:30 p. m., over an area 10 to 15 miles wide. The covering of an Army blimp, temporarily stationed at the Oklahoma City Municipal Airport, punctured and deflated. Loss to growing crops $20,000; to buildings and other property $35,000; path about 35 miles long.
Cushing, Okla., 7 miles north	9	6:30 p. m.	880	0	50,000	Tornado	3 persons injured; church and several buildings demolished. Damage to property and loss to crops; path 10 miles long.
Graham, Tex., vicinity of	9	7 p. m.	100	0	500	do	Barns demolished. Storm passed through uncultivated area.
Maud, Okla.	9	7:30 p. m.	440	0	75,000	do	4 persons injured; property damage $40,000; crop loss $15,000; path about 10 miles long. Strong wind accompanied this storm between 7 and 8 p. m. over an area 10 miles wide and of unknown length, causing damage at St. Louis to houses and oil rigs to the extent of $20,000.
Sasakwa, Okla.	9	8:30 p. m.	[1] 4–5		25,000	Wind	Oil derricks damaged.
Allen, Okla.	9	9 p. m.			20,000	do	Oil derricks and dwellings damaged to the extent of $15,000; crop loss $5,000; path narrow.
Nashoba, Okla., and vicinity	9	11 p. m.	440	0	3,500	Tornado	Several houses and barns destroyed; property damaged $3,000; crop loss $500; path 9 miles long.
Carroll and Boone Counties, Ark.	9	11–11:30 p. m.	880	1	125,000	do	50 persons injured, 8 seriously; 75 buildings demolished or damaged with estimated damage of $75,000; loss in orchards $50,000; path 15 miles long.
Benton County, Ark.	9				10,000	Wind	Barns and outbuildings blown down and overturned; loss to unharvested grains.
Fort Smith and Greenwood, Ark.	9			1	10,000	do	Damage at Fort Smith, roof of a building was blown off; lineman, in Greenwood, electrocuted.
Logan County, Ark.	9				10,000	do	Roofs and awnings damaged; numerous windows broken.
Xenia, Ill., 2 miles east	9				2,500	do	Barn and outbuildings on a farm destroyed.
Carroll and Boone Counties, Ark.	9–10				95,000	Heavy rain	Railroad roadbed and trestle, damaged to the extent of $75,000. In Eureka Springs, streets, buildings and contents, damaged, with $20,000 loss.
Boyd-Silesia, Mont.	10	4 p. m.	[1] 5		60,000	Hail	Culverts and bridges on farms and highways washed out; loss to crops $40,000; property damage $20,000; path 16 miles long.
Silver Star to Waterloo, Mont.	11	3 p. m.	[1] 3		3,000	do	Crop loss $3,000; property damage not estimated.
Philadelphia, S. C., vicinity of	11	3:30 p. m.	[1] 2		149,800	do	Crop loss $147,800; property damage $2,000; path 7 miles long.
Park City, Mont., vicinity of	11	6 p. m.			17,500	do	Loss to crops $15,000.
Billings, Mont., vicinity of	11–12			2	1,750,000	Rain and flood	Two-thirds of the city's area inundated to depths ranging from a few inches to 3 feet. Basements and first floors of residential and business sections flooded. Sheep herder caught with his flock of sheep and drowned. Loss to livestock.
Hinsdale, Mont., vicinity of	11–12				3,500	do	Great Northern Railway tracks and about 40 feet of the main highway washed out; traffic delayed for 2 or 3 days.
Roundup and Klein, Mont., vicinity of.	11–12				100,000	do	Heaviest loss occurred in the connection with the washing out of 2 main highway bridges, railway tracks and ballast, and the destruction of several houses at Klein. Power lines carried away by water. Crop loss $40,000; loss to poultry and sheep $1,000.
Wallace, S. Dak.	12	11:30 a. m.	67	0	800	Tornado	Several buildings wrecked.
Monument to Menlo, Kans., and vicinity.	12	5 p. m.	[1] 4		225,000	Heavy hail and rain	Loss chiefly to wheat; path 15 miles long.
Hill City, Kans., north and and east of.	12	7:30–8:15 p. m.	[1] 4		3,000	do	Bridges, roofs and gardens damaged; path 7 miles long.
Hastings and Juniata, Nebr., and vicinity.	12	P. m.		0	12,000	3 tornadoes	Buildings on 1 farm demolished and others damaged.
Webster County, Nebr.	12	do			3,500	Wind and hail	Loss to crops $3,000; property damaged $500.
Iowa	12				119,700	Thundersquall, heavy rain, and hail.	The storm swept over much of the north-central and northeast portion of the State from Kossuth County to the Mississippi River and southeast to northern Benton County. Fields flooded.
Minnesota, extreme south-central counties.	12				19,000	Rain and flood	Basements flooded; highways damaged; lowlands inundated. Loss to prospective crops $14,000; property damaged $5,000.
Morristown, Walker, and Keldron, S. Dak., vicinity of.	12–13				30,200	Flood	2 bridges and several dams washed out; farm buildings destroyed.
Lafayette County, Wis.	13	1 a. m.			50,000	Severe squall	8 large barns and several smaller buildings leveled, many others damaged. Some loss to livestock.
Jasper County, Iowa	13	A. m.		0	45,500	Tornado	General damage to trees in path of storm; house unroofed; several barns and electric wires blown down.
Polk County, Iowa	13	do		0		do	Trees and buildings on 4 farms damaged.
Mahaska County, Iowa	13	1:30 p. m.		0	2,000	Tornado and hail	Funnel-shaped cloud observed; most damage to buildings.
Wright and Hamilton Counties, Iowa.	13	5–6 p. m.			5,100	Wind, rain, and hail	Damage estimated for Hamilton County only. Fields flooded; considerable soil erosion.
Rowena, Humboldt, and Sioux Falls, S. Dak.	13	5–7 p. m.	880–2,640		59,500	Heavy hail	Loss to crops.
Melott, Ind.	13	6–7 p. m.	55	0	15,000	Tornado	Crop loss $5,000; property damage $10,000; path 5 miles long.
Beckham County, Okla.	13	11 p. m.	[1] 5		80,600	Hail	Storm extended from south of Erick to Elk City, property damage in the latter place being $5,000. Crop loss over the entire area $75,600.
Dubuque County, Iowa	13	12 p. m.		0	3,000	Tornado	Buildings on several farms damaged or destroyed; trees broken.
Wapello County, Iowa	13			0	1,500	do	Damage to farm property.
Greensburg, Pa.	14	4 p. m.	17	0	50,000	do	Several barns and outbuildings destroyed; many trees uprooted; 2 persons injured; path 23 yards long.
Falmouth, Va.	14	do			1,500	Hail	Property damage $500; crop loss $1,000.
Lamont, Okla.	14	6 p. m.	440	0	45,000	Tornado and hail	Buildings and residences damaged; power lines blown down. $25,000 crop loss; path 2 miles long.

See footnotes at end of table.

TABLE 4.—*Severe local storms, June 1937*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Lahoma and Enid, Okla., vicinity of.	14	10 p. m.			$2,000	Wind, rain, and hail	50 large cottonwood trees leveled and an orchard of 25 trees destroyed; 2 barns blown over and small outbuildings damaged.
Trinidad, Colo.	14	P. m.	[1] 4			Hail	Ground covered with hail 6 to 10 inches deep. Much crop loss; property damaged; path 10 miles long.
Westmoreland and Somerset Counties, Pa.	14	do.			100,000	Wind, electrical	Most severe damage at Latrobe and Somerset. Near Pleasant Unity, 2 persons were injured and several buildings unroofed.
Brooklyn, Queens, Long Island, N. Y.[3]	14					Tornadic winds, electrical.	Trees uprooted; windows broken; poles and wires down; cellars flooded; several persons injured.
Fort Cobb, Okla., vicinity of.	14	3 p. m.	[1] 3-8		60,000	Hail	Crop loss $50,000; property damage $10,000; path 10 miles long.
Paducah, Tex.	14	P. m.	[1] 10		20,000	do	Property damaged.
Jefferson County, Ark., southeast portion.	15				2,000	Wind	Several barns unroofed; livestock killed.
Dane County, Wis.	15			0		Tornado	No details.
Baker County, Oreg.	16	9:22-9:35 a. m.			$8,000-$12,000	Tornado and hail	Barn wrecked; brick church moved about 15 inches off its foundation. Small buildings turned completely over and not damaged. A garage lifted from its foundation and thrown several feet leaving the car inside undamaged. Cow carried 60 feet through the air and deposited upside down without hair and skin. 5 large pine trees blown down around a house with no damage to the building. Woman walking on Main St. entangled by a barb-wire fence, being forced to remain during the storm, escaping with minor injuries. Chickens killed by hail; much loss to alfalfa; fields of grain near Halfway depleted; stock killed.
Lewis and Nez Perce Counties, Idaho.	16	10:30-11 a. m.	2,640		50,000	Heavy hail	Severe loss to crops in places amounting to $45,000; damage to roofs and windows $5,000.
Adams County, Idaho.	16	12:30 p. m.	880		2,000	Hail and wind	Crop loss $1,500; chickens killed; barn blown down; path 6 miles long.
Aberdeen, Md., vicinity of.	17	2:40-2:47 p. m.				Tornado	No damage.
Miles City, Mont., vicinity of.	17	6-7 p. m.	440		1,000	Hail	Hay and grain on 2 ranches destroyed.
Hazelton, Kans., vicinity of.	17	8-9 a. m.	[1] 4		50,000	Heavy hail and rain	Property damaged; path 12 miles long.
Prairie County, Mont., northeast portion.	17		2,640		20,000	Hail	Crop loss.
Wakefield, Nebr., vicinity of.	18	6:45 p. m.	20-234	0		Tornado	Minor damage to several buildings; a number of shade trees uprooted or broken.
Plymouth, Iowa.	18	7 p. m.		0	4,700	do	Buildings damaged or wrecked; loss to crops $200, to livestock $100.
Woodbury County, Iowa.	18	7:30 p. m.			2,500	Wind	Loss to crops.
Fall River County, S. Dak.	18	7:30-8 p. m.	[1] 10		200,000	Rain and hail	Heavy rain washed out 14 railroad bridges. Hail washed out crops and grass in its path; some stock killed.
Jackson County, Iowa.	18	10 p. m.			3,000	Heavy rain and flood.	Flood damage.
Knox and Pierce Counties, Nebr.	18	P. m.		0	40,000	Tornado	Buildings on 4 farms destroyed with estimated loss of $35,000; crop loss $5,000.
Iowa County, Iowa.	19	A. m.			500	Wind	Property damaged; small grains blown out.
Hancock County, Iowa.	19	6 p. m.		0		Tornado	Funnel-shaped cloud observed. Windmills, silos, brooder-houses and small buildings blown down.
Hamel and Maple Plain, Minn., and vicinity.	19	7 p. m.	440	0	12,500	do	Several barns, outbuildings, and windmills demolished or badly damaged; trees uprooted; loss to crops mostly grain; path 10 miles long.
Sumter County, S. C.	19	[oc] p. m.	[1] 6		196,000	Hail	Loss to crops; path 10 miles long.
Hancock County, Iowa.	19	8:30 p. m.			1,000	Wind	Loss to crops.
Howard and Winneshiek Counties, Iowa.	19	10 p. m.	67	0	11,500	Tornado	Funnel-shaped cloud observed; property damage $11,000; loss to livestock $500.
Minnesota, extreme southern border Counties.	19	P. m.			10,000	Thunderstorm	Considerable damage to farm buildings; in spots small grains badly lodged
Lee County, S. C.	19	do.			5,000	Hail	Loss to crops.
Newberry County, S. C.	19	do.			6,000	Electrical and hail	Loss to crops due to hail $5,000. 2 barns burned.
Goldville, S. C.	19				25,000	Electrical	School burned.
Jackson County, Iowa.	20	2 a. m.			10,000	Wind and flood	Loss to corn crop.
Fort Wayne, Ind., and vicinity.	20	7 p. m.			1,000	Thundersquall	Barn demolished, trees uprooted and, power and telephoned lines damaged.
Winneshiek County, Iowa.	20	10 p. m.		0	8,200	Tornado	Funnel-shaped cloud observed; damage to buildings $8,000; loss to livestock $200.
Michigan, south and east portions.	20	P. m.		8	3,000	Thundersquall	4.5 inches of rain in 12 hours threatened to break a dam at Michigan Center where the city of Jackson controls the flow of the Grand River. Brooklyn and Jackson isolated. Much property damage reported. In the vicinity of Leslie, lightning destroyed a barn with loss of $3,000. 6 persons drowned; 2 persons lost their lives because of accident.
Epworth, Iowa, vicinity of.	20			0		Tornado	Buildings leveled in one place with no further damage in the vicinity.
Fremont County, Iowa.	20			0		do	Several farm buildings destroyed.
Locust, Iowa, vicinity of.	20			0	10,000	do	Buildings on several farms damaged or wrecked.
Riceville, Iowa, and vicinity.	20				50,000	Squall	Large trees uprooted; automobiles damaged by falling trees; buildings on several farms wrecked or damaged; hangar and new airplane destroyed.
Darlington, S. C.	20				1,500	Electrical	Dwelling burned.
Rembert, S. C.	20				1,700	do	2 barns, 1 filled with hay, burned; horse killed.
McHenry County, Ill.	21				38,000	Heavy rain and flood.	Roads and bridges washed out; property damage $20,000; crop loss $18,000
Woodstock, Ill.	21				20,000	Wind	Property damaged.
New York, west portion.	21				2,000,000	Heavy rain and flood.	Much damage to property, and highways; loss to crops.
Cleveland, Ohio, and vicinity.	21				17,000	Thunderstorms and hail.	Several storms during the day. Excessive rain caused serious flooding and damage from hail in western suburbs.
Helena, Mont.	22	12:50 - 1:31 p. m.			2,000	do	Sidewalks covered with water, in one place being 15 inches deep. Visibility reduced and traffic at standstill. Damage chiefly due to water seeping into basements, spoiling merchandise.
Madison County, Mont.	22	2 p. m.	[1] 4		15,000	Rain and flood	Loss to crops $10,000; property damage $5,000.
Kenmare, N. Dak.	23			0		Tornado	Trees uprooted, poles down, farm buildings wrecked, and stock killed.
Indiana; extreme northeastern counties.	24				25,000	Thundersquall	Damage to high school gymnasium in Howe.
Sandusky, Ohio.	25	2:10-10 a. m.				Thunderstorm	Flooding caused much loss to growing crops and property damage.
Walsenburg, Colo.	25	12:15-1 p. m.	[1] 2			Severe hail	Considerable crop loss and property damage.
Clinton, Iowa, and vicinity.	25	2:05 p. m.			25,000	Thundersquall	Street flooded; sewers inadequate; property damaged.
Rush, Colo.	25	3-3:15 p. m.	[1] 5			Severe hail	Several thousand dollars' crop loss; path 90 miles long.
Dunbarton, Wis., vicinity of.	25	3:30 p. m.	100	0	10,000	Tornado	Large dairy farm wrecked; considerable minor damage; path 12 miles long.
Wapello County, Iowa.	25	5 p. m.			10,000	Wind	Loss to crops.
Benton and Warren Counties, Ind.	25	P. m.	[1] 10		125,000	Straight—line wind	$75,000 damage to buildings, trees, and power lines; $50,000 crop loss.
Kosciusko and Elkhart Counties, Ind.	25	do.			100,000	do	Damage to farm and utility property. This storm occurred an hour or so earlier than in Benton and Warren Counties.
Freeport, Ill.	25				590,000	Rain and flood	Property damage $50,000; crop loss, principally to corn and oats, $540,000.
Mt. Carroll, Ill.	25				1,000	Wind	Property damaged.
Papineau, Beaverville, and Woodstock, Ill.	25				20,000	do	Property damage $5,000; crop loss $15,000.
Iona, Mich., and vicinity.	25				13,000	Thundersquall and hail.	Power lines and equipment damaged. Several store windows broken; trees down.
Belleville, Wis., and vicinity.	25		880		4,000	Wind and rain	2 barns and 2 silos blown down; a barn unroofed and several others moved on their foundations; 30 large trees uprooted; field badly washed; path a mile long.

See footnotes at end of table.

TABLE 4.—*Severe local storms, June 1937*—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks
Lafayette County, Wis	25			0	$10,000	Tornado	Damage to farm buildings.
Hennepin and Carver Counties, Minn.	26	5:30–7 p. m.	133		5,000	Thunderstorm	Farm building damaged; small grain lodged; path 2 miles long.
Mitchell County, Iowa	26	9:30 p. m.			500	Wind and rain	Property damaged; grain beaten down; some corn washed out.
Jasper, Ind	26				1,000	Thundersquall	Damage to business property. Crop loss additional, amount not reported.
Cumberland County, Va	27	3:30–4:30 p. m.	[1] 8		3,000	Hail	Loss in corn and tobacco crops $3,000; property damaged.
Faulkton, S. Dak., vicinity of	27	5 p. m.	[1] 2			do	Crops destroyed.
Buchanan County, Iowa	27	8 p. m.	100	0	1,000	Tornado	Damage confined to one farm where buildings were wrecked and trees uprooted.
Fort Worth, Tex	27	9:30 p. m.	150	0		do	Small property damage reported.
Sulphur, Okla	28	8–10 a. m.	[1] 10		15,000	Wind	Crop loss $10,000; property damage $5,000; path 15 miles long.
Duncan, S. C., and vicinity	28	2:10 p. m.	2,640		20,000	Hail	Loss to crops.
Perkins, Ga., vicinity of	28	3 p. m.	880–3,520	0	5,000	Tornado	Property damaged; path 10 to 20 miles long.
Hamilton County, Iowa	28	5 p. m.	[1] 1		7,000	Hail	Loss to grain.
Baird, Tex	28	5:30 p. m.	[1] 2		6,500	do	No details.
Monona County, Iowa	28	6:30 p. m.			500	Wind and hail	Loss to crops.
Polk County, Iowa	28	do	[1] 3		3,000	do	Property damaged; loss to small grains; crops entirely ruined over an area about 5 miles square. Crop loss not estimated.
York County, Nebr	28	P. m.	[1] 1		2,500	Hail	Loss to crops.
Boykin, S. C., vicinity of	28	do			5,000	do	Crop loss.
Columbia City, S. C., and vicinity.	28	do			8,000	Thunderstorm	Damage to city streets with highway and property damage outside of city.
Camden and Rembert, S. C., and vicinity.	28				2,000	Electrical	Filled tobacco barn and several others burned; horse killed.
Kalispell, Mont., vicinity of	29	8:15 p. m.				Wind	Several power poles blown down; trees broken; flower beds and gardens damaged.
Newberry County, S. C	30	2–3 p. m.	[1] 3		175,000	Hail	Loss to crops; path 35 miles long.
Anderson County, S. C	30	2:30 p. m.	[1] 5		50,000	do	Loss to crops; path 5 miles long.
Liberty Hill and Lugoff, S. C.	30	3 and 7 p. m.	1		25,000	do	Loss to crops.
Lee County, S. C., western edge to below Bishopville.	30	4–5 p. m.	5		200,000	do	Loss to crops; path 15 miles long.

[1] Miles instead of yards.
[2] From press reports.

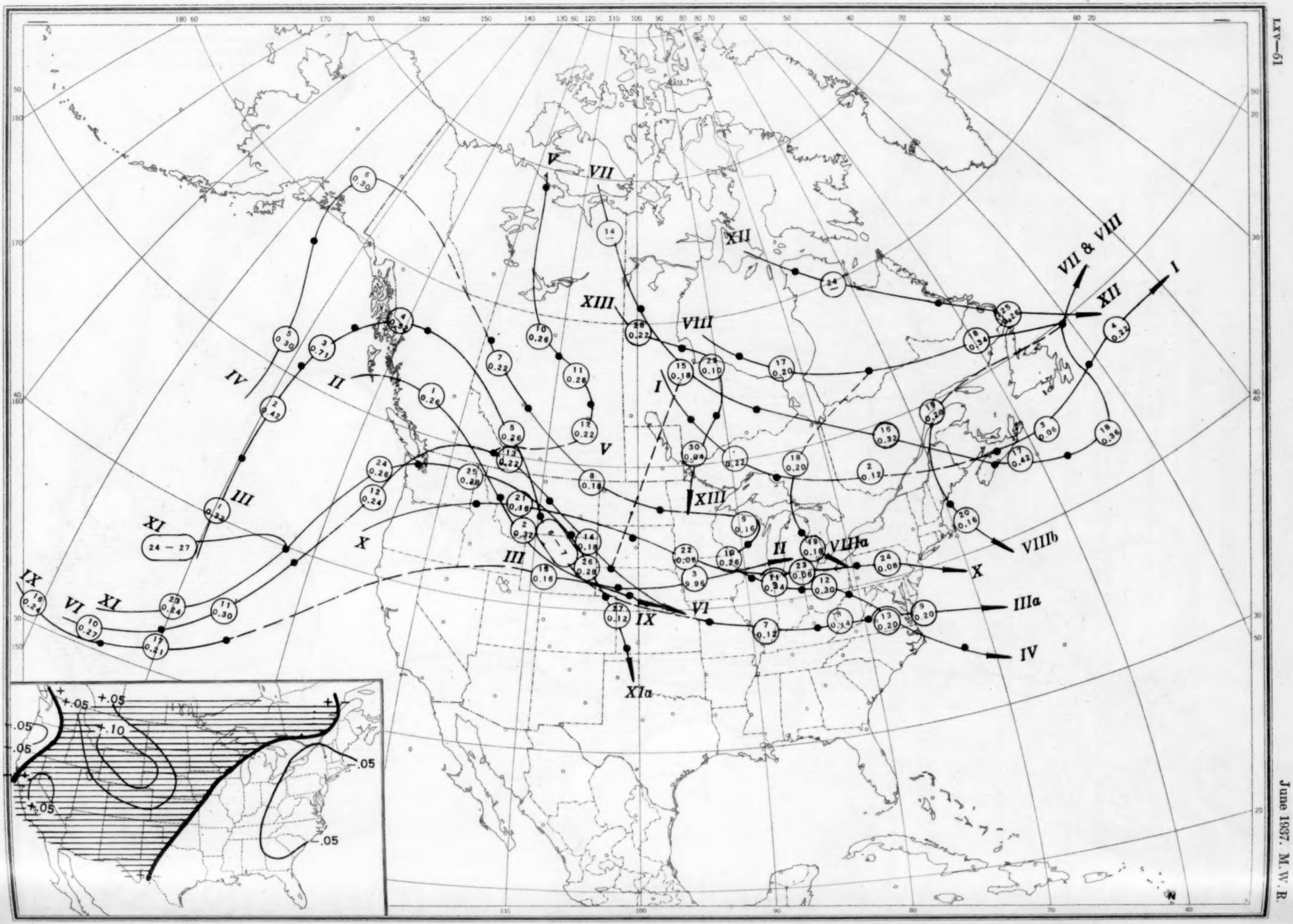
Chart I. Departure (°F.) of the Mean Temperature from the Normal, June 1937

Chart I. Departure (°F.) of the Mean Temperature from the Normal, June 1937

Shaded portions show excess (+)
Unshaded portions show deficiency (−)
Lines show amount of excess or deficiency
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, June 1937. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by W. P. Day)

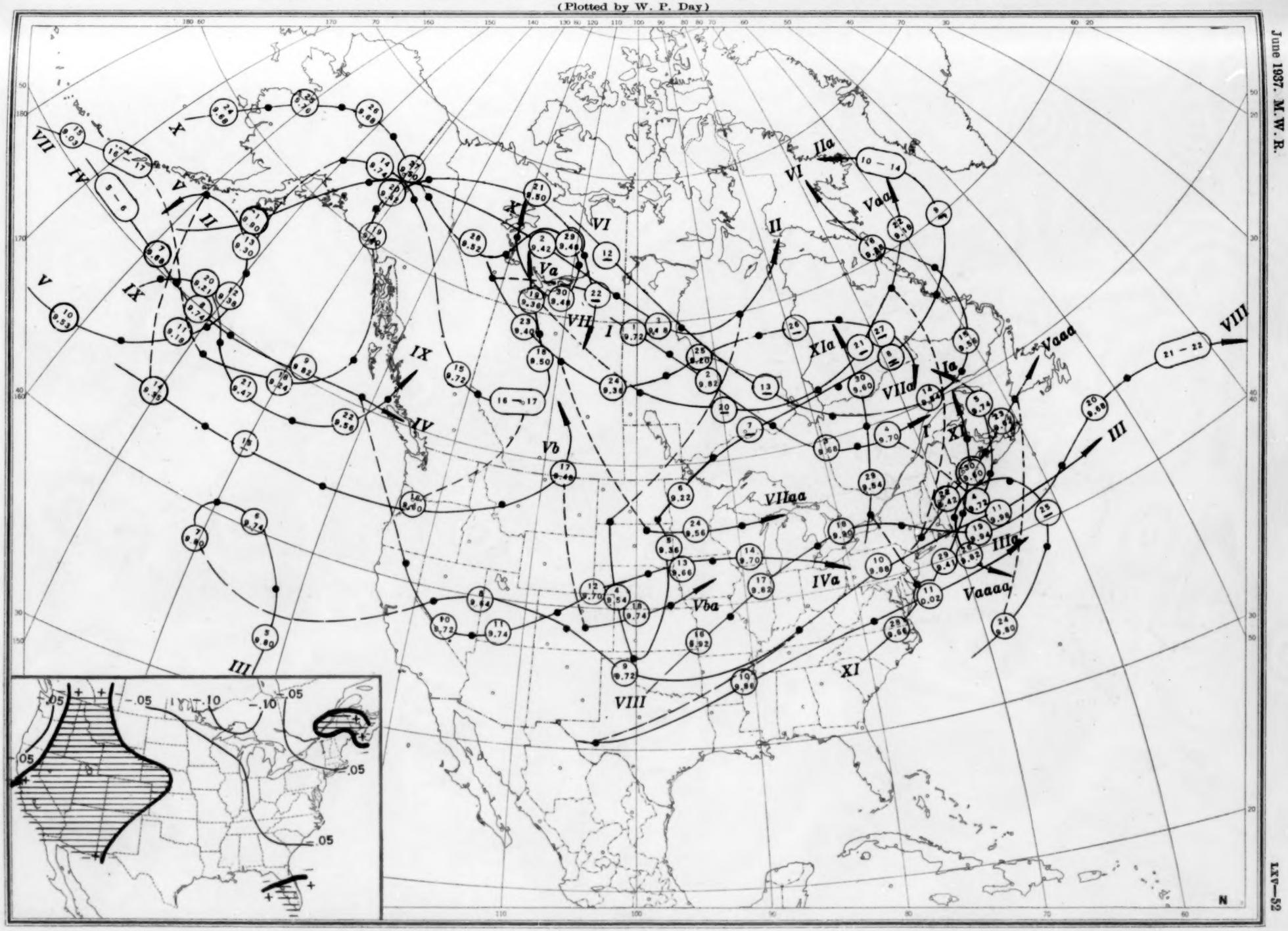


Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Circle indicates position of anticyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 7:30 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, June 1937. (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by W. P. Day)



Circle indicates position of cyclone at 7:30 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 7:30 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky Between Sunrise and Sunset, June 1937

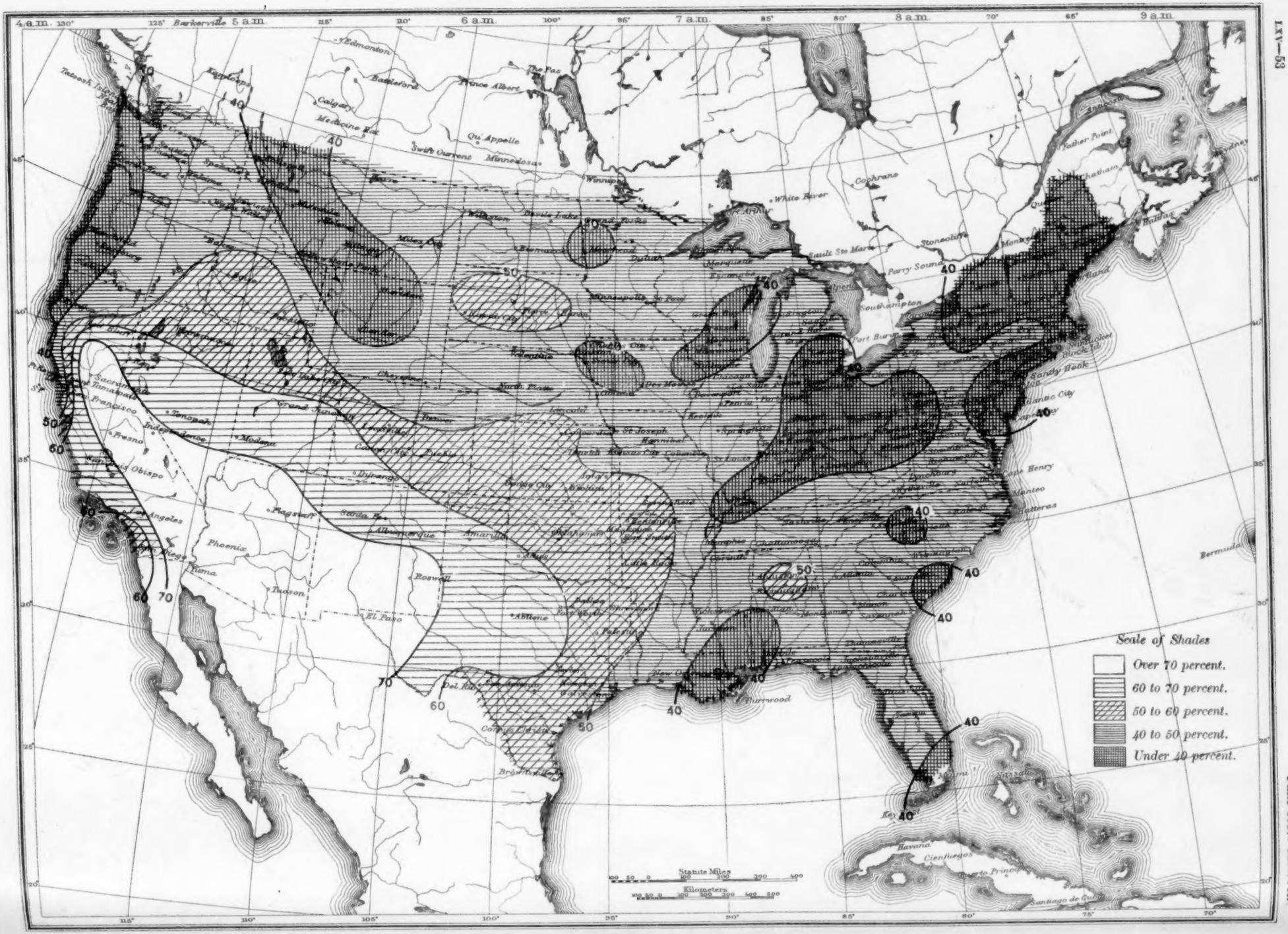


Chart V. Total Precipitation, Inches, June 1937. (Inset) Departure of Precipitation from Normal

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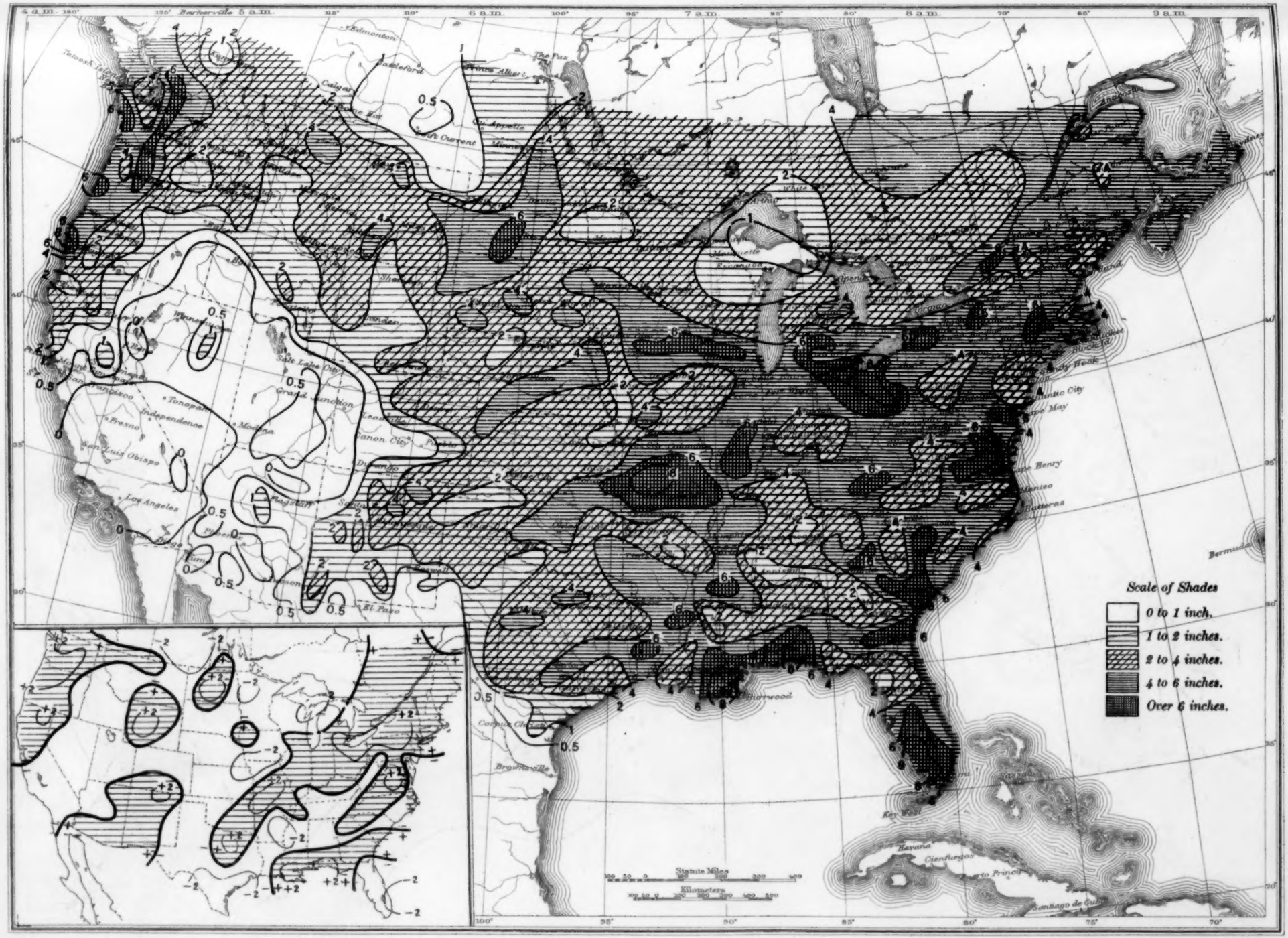

Chart VI. Isobars at Sea Level and Isotherms at Surface; Prevailing Winds, June 1937

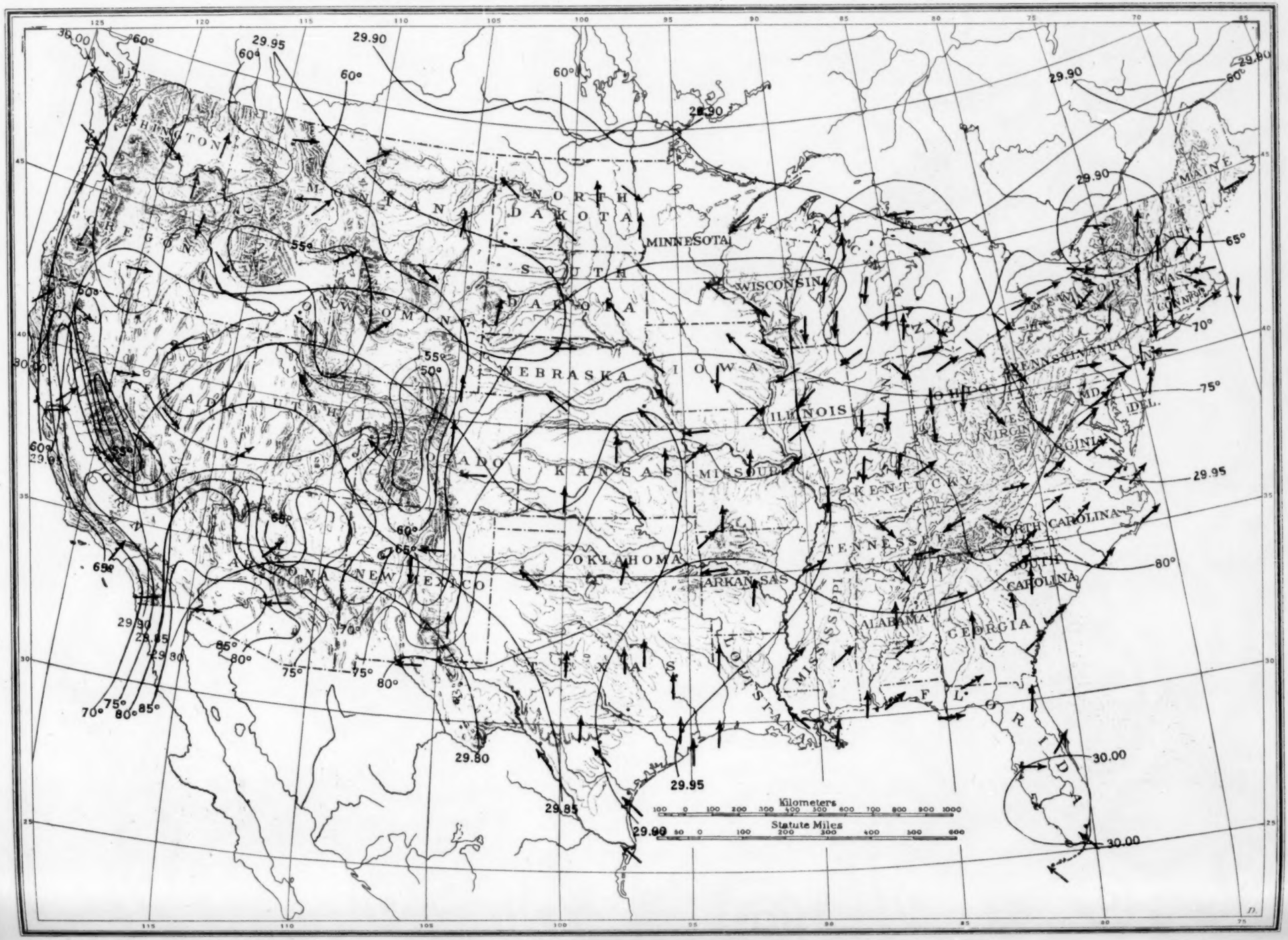

Chart VII. Wind Roses for Selected Stations, June 1937

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(Plotted by W. W. Reed)